PEA AND LENTIL FIELD GUIDE

BASF
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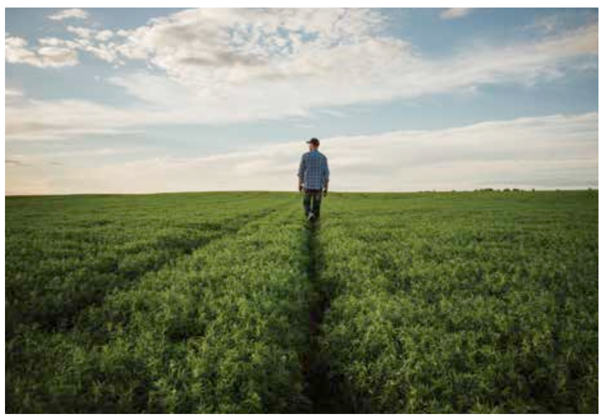

The secret to growing peas and lentils? It’s all in the details.

This agronomy guide is designed to help growers and agronomists overcome the challenges of pea and lentil production to get the most out of every acre. This comprehensive guide will take you through the specifics from crop establishment to harvest management. You will gain a better understanding of the key growth stages in both crops and discover the necessary practices for successful establishment. You will also learn more about effective integrated management strategies for weeds, disease and insects. And finally, with tips for the most efficient harvest possible, your pulses will be on the right path to success.

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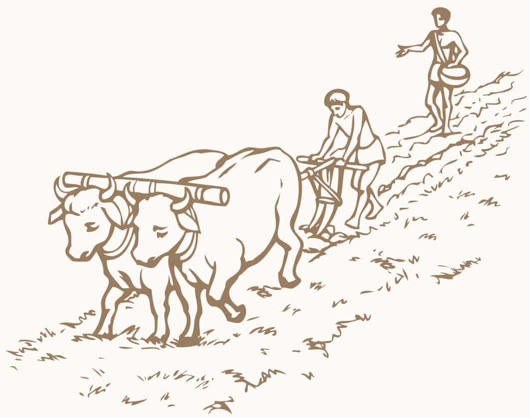
Chapter 1 – Introduction to peas and lentils.

Lentils (*Lens culinaris* subsp. *culinaris*) are annual legumes named for their lens shaped seeds. It may have been one of the first domesticated crops, with evidence dating back to 8500 – 7500 B.C.[1] While the exact location is unknown, the origin of the lentil has



been traced to the Fertile Crescent: a crescent-shaped area that extends from the Persian Gulf through present-day Iraq, Syria, Lebanon, Jordan, Israel, and northern Egypt. Cultivation of the crop spread west into Europe and immigrants to North America brought seeds with them to grow lentils in the New World. Lentils are cropped in dry (semi-arid) regions of the world, ranging from Bangladesh to Morocco, Russia to Ethiopia and Canada to Australia.[2]

Field peas (*Pisum sativum* L. subsp. *arvense*) are also annual legumes. Similar to lentils, it is thought to have been one of the first cultivated crops dating back to 9000 – 8000 B.C. Its origin is relatively unknown, with different research pointing toward the Mediterranean, the Fertile Crescent, Ethiopia along with other regions.

In Canada, pulses are grown in the prairie provinces of Manitoba, Saskatchewan, Alberta and to a very small extent, British Columbia. Saskatchewan grows 90% of Canada's lentils, with Alberta producing the remaining 10%. In 2015, Canada produced 2.3 million tonnes of lentils and 3.2 million tonnes of field peas.

Globally, the countries with the current highest annual lentil production include Canada followed by India, Turkey, Australia, and Nepal.[3] India is not only one of the top producers of lentils, it's also the top importer. As of 2014, the countries which produce the highest amount of field peas are Canada, China, Russia, USA and India. Canada is the world's top exporter of lentils and peas, working with 150 markets around the world. In lentil exports, Canada is followed by Australia, USA, Turkey, and UAE, whereas in field pea exports, Canada leads USA, Russia, France, and Australia.

1 Alo, F., Furman, B.J., Akhunov, E., Dvorak, J., and P. Gepts. 2011. Leveraging Genomic Resources of Model Species for the Assessment of Diversity and Phylogeny in Wild and Domesticated Lentil. Journal of Heredity. 102(3): 315-329.

2 Erskine, W., Muehlbauer, F.J., Sarker, A., and B. Sharma. 2009. The Lentil: Botany, Production and Uses.

3 FAOSTAT. 2015.

Lentils and peas are both primarily used for human consumption. Typically, lentils and peas are consumed whole or split. Additional products such as isolated starches, proteins, and fibres are developed through additional milling and processing. These crops are also used for livestock feed and forage. Pea protein has significant uses in poultry, swine and ruminant feeds, while both lentils and peas are used in pet food and aquaculture. Because of the lower levels of trypsin inhibitors compared to soybeans, pulses can be added to livestock diets without having to undergo heating and extrusion processes.[4]

Peas contain approximately 21 to 25% protein. The seeds are low in fat, high in fibre and contain the nutrients copper, folate, manganese and thiamin. Lentils are also high in protein, containing about 25% protein in the seed.[5] The remainder of the seed is comprised of 1% fat, and 56% carbohydrates.[5] Like peas, lentils are high in folate, manganese, thiamin, and fibre.

It's been shown that as GDP and disposable income increase, diets with plant-and animal-based protein also tend to increase. Lentils and peas are an excellent source of plant-based protein and as populations grow, the demand for pulses continues to increase.

There are several key industry organizations in Canada that contribute to pulse research. They provide information and represent both producers and the industry, including processors and traders. These organizations include Pulse Canada, Alberta Pulse Growers Commission, Saskatchewan Pulse Growers, Manitoba Pulse Growers Association and the Crop Development Centre at the University of Saskatchewan. These groups are champions for the pulse industry, they invest in lentil and pea research and promote Canadian pulses in world markets. Some of the current research being funded by these groups include, effects of vertical tillage on pulse crop yields, development of biofertilizers for pulse-based crop rotations, weed management in pulses, integrated pest management of the pea leaf weevil, fertilization of lentils with zinc in Saskatchewan to increase yield, development of pea and lentil varieties with more determinant growth characteristics, and aphanomyces screening with rapid generation technology for peas and lentils.

As a result of an increasing world population and higher dietary demands, pulse cultivation has reached an all-time high in Western Canada and will continue to hold at these levels for the foreseeable future. Pulses are not only an important crop for dietary reasons, they're also vital for the sustainability of agriculture in Western Canada. Their ability to produce their own nitrogen within a growing season as well as some residual nitrogen for subsequent crops, leads to a healthier soil profile, especially when pulses are followed by crops like canola or wheat. As one of the global leaders in pulse production, Canada has both the opportunity to take advantage of the growing demand and the responsibility to develop and share research and information to help growers get the most out of every pulse acre.

4 Endres, G., Forster, S., Kandel, H., Pasche, J., Wunsch, M., Knodel, J., and K. Helleyang. 2016. Field Pea Production. North Dakota State University Extension Service, Fargo, ND, USA.

5 Adsule, R. N., Kadam, S. S., and H. K. Leung. 1989. Lentil. In: Handbook of World Food Legumes: Nutritional Chemistry, Processing technology, and Utilization. Eds: Salunke, D.K., and S.S. Kadam. CRC Press: Boca Raton, FL, USA. Vol 2: 131-152.

Back to basics – Lentils.

Lentils are often described and differentiated by their size range and colour in Western Canada.

There are two types of lentils based on seed size:

- Large – > 50 g/1000 seeds
- Small – < 40 g/1000 seeds

Green lentils (large, or Chilean, Figure 1.1)

- Green seed coat, yellow cotyledon
- Small, medium and large seed sizes

Red lentils (small, or Persian, Figure 1.2)

- Grey seed coat, red cotyledon
- Extra-small, small, and medium seed sizes

Specialty lentil types.

French green (verde or du puy, Figure 1.3)

- Green-marbled seed coat, yellow cotyledon

Green cotyledon

- Green or green-marbled seed coat, green cotyledon

Spanish brown (Figure 1.4)

- Grey-dotted seed coat, yellow cotyledon

Figure 1.1. Green lentils.

Figure 1.2. Red lentils.

Figure 1.3. French green lentils.

Figure 1.4. Spanish brown lentils.

Key growth stages – Lentils.

Germination.

Lentil seeds undergo hypogeal germination (Figure 1.5) where the cotyledons remain below the soil surface after germination. Remaining below the soil surface provides protection to the seedling. The scale node is the first node of a lentil plant and it develops underground. The second scale node develops either underground or at the soil surface. These two nodes provide an opportunity for regrowth if the aboveground main shoot is damaged (i.e. frost, hail, insect, herbicide injury). A new shoot may arise, under stressful conditions, from one or both scale nodes beneath the soil surface.

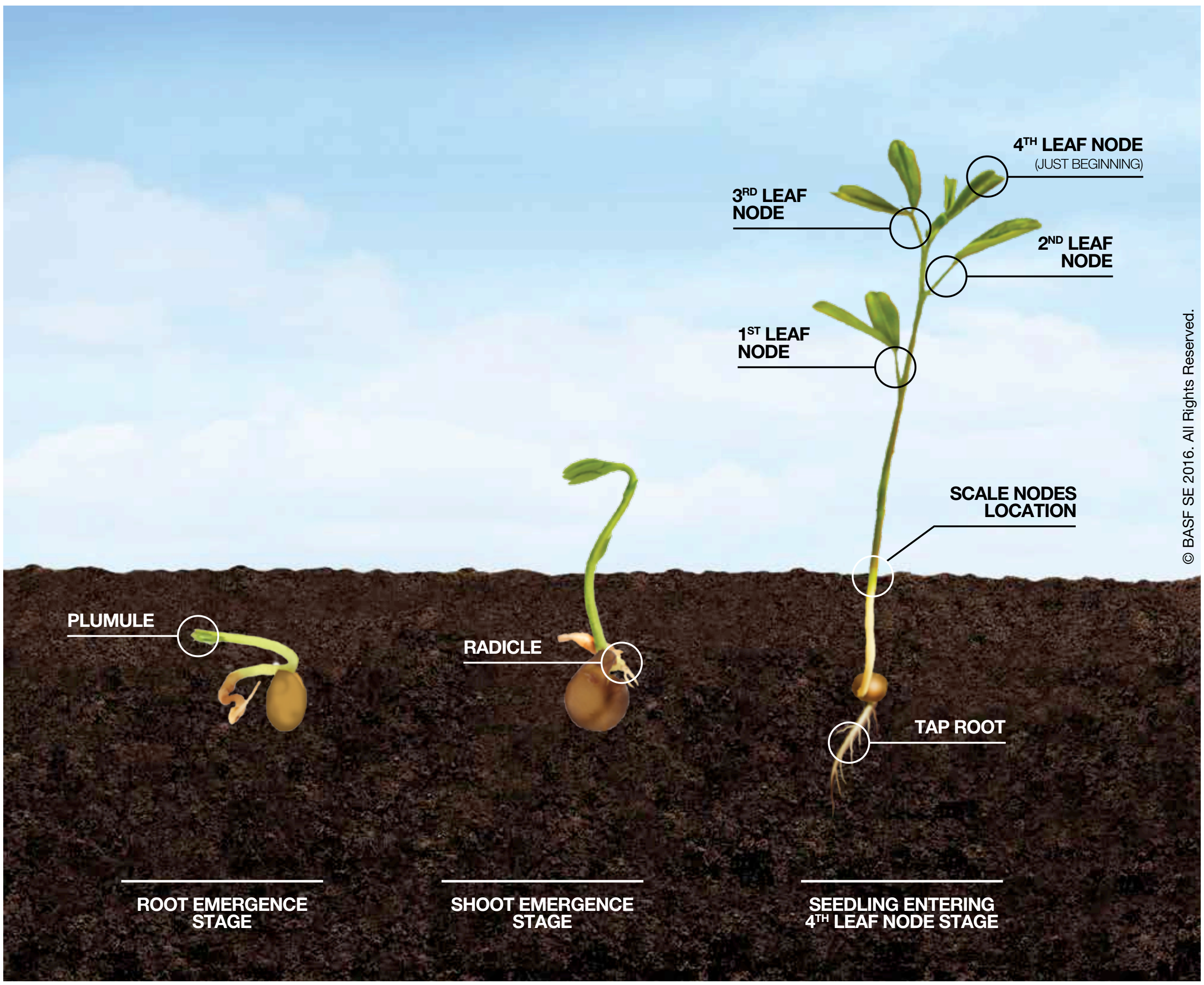


Figure 1.5. Lentil germination and emergence.

Vegetative growth. (Figure 1.5)

- Shallow root system, 0.6 m
- First leaf occurs at the 1st leaf node
- Successive nodes produced every 4 to 5 days
- Leaves 5 cm long with 9 to 15 leaflets per leaf
- Plants are generally short, 20 to 75 cm
- Right before flowering, a tendril grows at tip of new leaves
- Prone to lodging due to fragile stems

Figure 1.6. *Lens culinaris* flowers.

Flowering. (Figure 1.6)

- Flowers form from base of leaves
- Flowering begins on lower branches and moves up plant until harvest
- Clusters of 2 to 3 white or light purple flowers
- Flowers self-pollinate
- Early cultivars flower at the 11th to 12th node stage
- Late cultivars flower at the 13th to 14th node stage
- Flowers that form after first week of August may not form seeds by harvest
- Lentils have an indeterminate growth habit and will keep flowering until they encounter stress to shut the plant down

Figure 1.7. Secondary aerial branches.

Maturity.

- Under ideal conditions, 2 or more additional primary shoots may form off the stem base
- Up to 5 secondary branches can form off the main stem; these represent the greatest contributors to seed yield
- Secondary (aerial) branches can form from upper nodes of the main stem (Figure 1.7)
- Under ideal conditions, additional branches can form off the secondary aerial branches and bear seed
- Pods are < 2.5 cm in length, containing 1 or 2 seeds (Figure 1.8)
- Since lentils are indeterminate, the presence of a stressor (i.e. drought, heat, frost, damage, nutrient stress or chemical desiccant) is especially important under conditions that favour vegetative growth

Harvest options.

As mentioned, continuous flowering and crop immaturity is a challenge for pulse growers. Lentil plants need to mature for the seed and plant material to dry down so harvest can commence. There are two methods that producers can use to achieve this.

1. Harvest aids and desiccants are chemicals that can be applied to dry down the crop. This method is used when straight cutting pulses.

2. Swathing is another option used to dry down the crop. For lentils, the average number of days from seeding to appropriate swathing ripeness is:

    - 100 days for early varieties
    - 110 days for very late varieties

See Harvest management chapter (page 57) for more details.

Plant adaptation.

Figure 1.8. Lentil pods.

Lentils are quite tolerant to heat, frost and drought but they don't do well in excessive moisture. The best yield productivity occurs when the crop receives 15 to 25 cm (6 to 10") of moisture. Too much moisture prior to full bloom can negatively impact seed set, while too much moisture around harvest is favourable for disease development.

In general, lentil plants are sensitive to boron toxicity, saline conditions and excessive moisture. They do best when grown on level ground with a soil pH of 6.0 to 8.0, in the Brown, Dark Brown and Moist Dark Brown soil zones of Western Canada. (Figure 1.9,1.10). However, breeding has allowed the growing area to extend into the Thin Black and Black soil zones. This is because newer varieties are more determinant and have some level of disease tolerance to the pathogens in those zones. The determinant characteristic means the crop has an improved chance of reaching maturity before encountering a stressor. Stressors are typically needed to stop flowering in lentils and often occur as periods of heat or drought in the Brown soil zones. The Black and Grey soil zones are not appropriate for lentil growth because of excessive moisture, which favours vegetative growth. Wet conditions in those areas increase the disease pressure and slow maturity, which means the growing season will be unfavourable for lentil production.

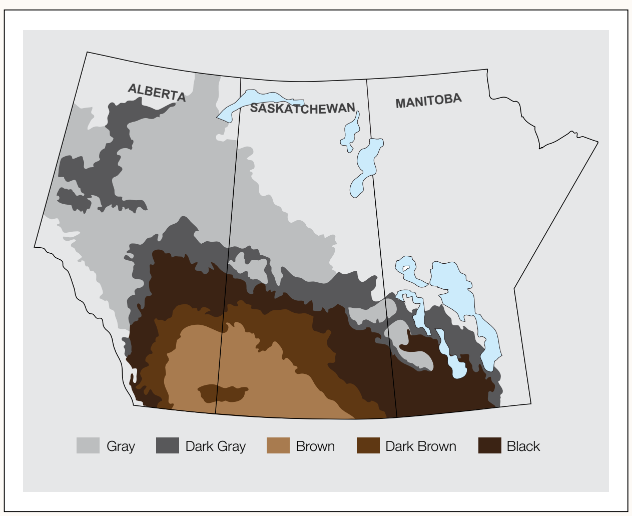


Figure 1.9. Western Canadian soil zones.
Source: Yan, W., Fetch, J.M., Fregean-Reid, J., Rossnagel, B., and Ames, N. 2011. Genotype x location interaction patterns and testing strategies for oat in the Canadian Prairies. Crop Science Society of America. 51(5): 1903-1914.

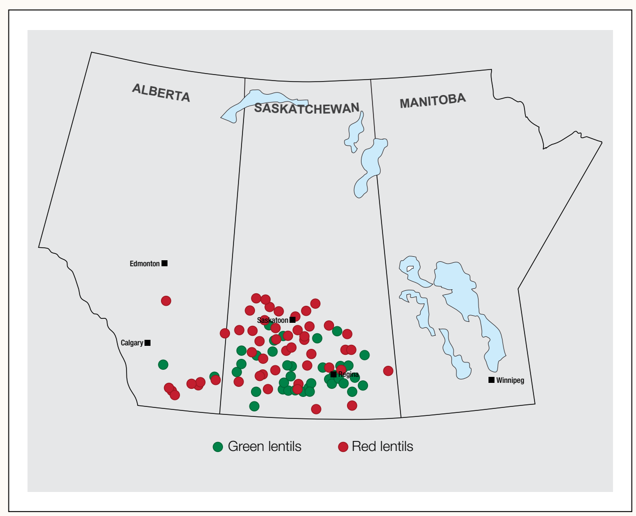


Figure 1.10. 2015 red and green lentil growing regions.
Source: Wang, N. 2015. Quality of Western Canadian Lentils. Canadian Grain Commission.

Back to basics – Field peas.

Field peas are often described by their seed colour.

- Green pea = green seed coat (Figure 1.11)
- Yellow pea = yellow seed coat (Figure 1.12)
- Red pea = red seed coat

Figure 1.11. Green field peas.

Figure 1.12. Yellow field peas.

There are several other specific field pea classifications, based on their use. These include:

Dun peas (Figure 1.13)

- Pigmented seed coat, yellow cotyledon (seed coat characteristic provides root rot protection)
- Dehulled for human consumption, similar to yellow varieties

Maple peas (Figure 1.14)

- Pea sprouts and bird food
- Some cultivars are used for silage

Marrowfat peas (Figure 1.15)

- Non-pigmented seed coat, green cotyledon
- Used for signature 'mushy peas' in UK and for snack foods in Asia

Forage peas

- High biomass, lodge-resistant

Figure 1.13. Dun peas.

Figure 1.14. Maple peas.

Figure 1.15. Marrowfat peas.

Key growth stages – Field peas.

Germination.

Like lentils, field pea plants undergo hypogeal germination (Figure 1.16), where the cotyledons remain below the soil surface following germination. This form of germination provides protection to the pea seedling and helps it emerge from a greater planting depth compared to other crop seeds. If damage occurs to the main shoot of the pea seedling, regrowth can occur from the two small scale nodes that develop first and that remain either underground or just at the soil surface. The scale nodes also function as axillary buds or a bud that grows from the axil of a leaf and may develop into a branch or flower cluster.[6]

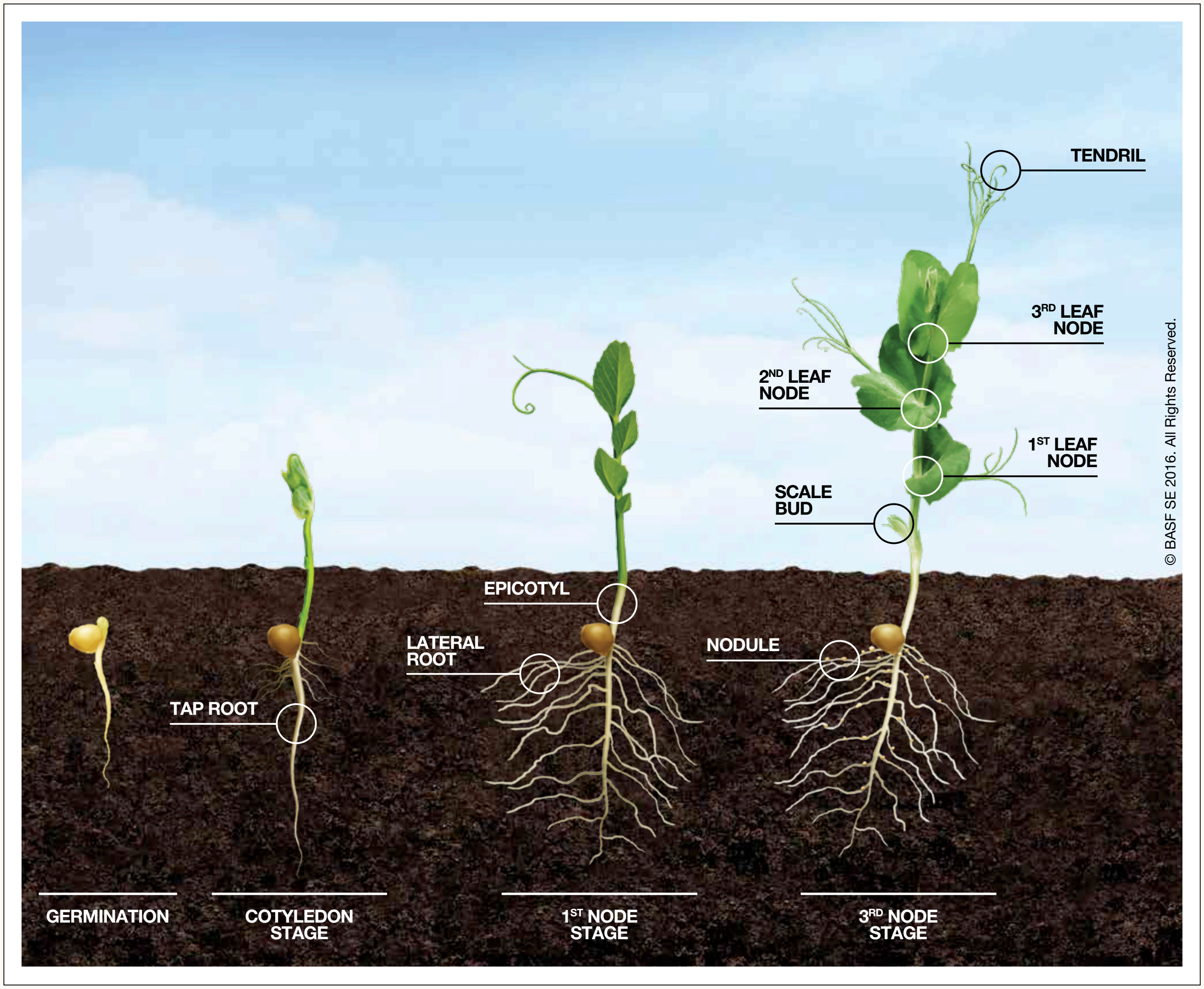


Figure 1.16. Field pea germination and emergence.

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[6] McKay, K. 2005. Growing Peas and Lentils Key Growth Stages. North Dakota State University Agriculture. Minot, ND, USA.

Vegetative growth. (Figure 1.16)

- The first leaf emerges at the 1st leaf node
- A pair of leaflets and a tendril form at each leaf
- An internode develops between each successive leaf node
- Two nodes develop every 7 days
- Branching can occur at the lower nodes
- Semi-leafless or 'afila' pea plants have tendrils in place of leaflets
- Tendrils aid in plant climbing and intertwining and can help prevent crop lodging (most cultivars demonstrate this)
- Typically, only have one stem but can tiller when stressed (i.e. damage by pests or weather)

Flowering. (Figure 1.17)

- Flowering begins between the 12th and 16th node stages
- 1 to 3 flowers develop at each node
- Flowers are in clusters located between the leaf stalk and the plant stem[7]
- Flowers are white or occasionally purple (forage types) and can self-pollinate
- 13 to 23°C is the optimal temperature range for flowering and to avoid flower blast
- Flowering typically lasts 2 to 4 weeks
- Similar to lentils, most field pea varieties continue to flower until they encounter a stressor

Maturity. (Figure 1.18)

- Most Canadian-grown cultivars are indeterminate
- Pods are 4 to 10 cm long and 1 cm wide
- Pods contain 6 to 8 seeds
- Mature seeds can be smooth or wrinkled and can be a variety of colours depending on cultivar

Harvest options.

Field pea varieties with medium maturity reach swathing ripeness in 90 days. Earlier or later ratings beyond medium adds three or four days. Like lentils, harvest aids and desiccants are often used to dry down the field pea crop, followed by straight cutting with a combine. See Harvest management chapter (page 57) for more details.

Figure 1.17. Field pea flowers.

Figure 1.18. Field pea pods.

7 Oelke, E.A., Oplinger, E.S., Hanson, C.V., Davis, D.W., Putnam, D.H., Fuller, E.I., and C.J. Rosen. 1991. Dry Field Pea. In Alternative Field Crops Manual. University of Wisconsin-Extension, Cooperative Extension. University of Minnesota: Center for Alternative Plant & Animal Products and the Minnesota Extension Service.

Plant adaptation.

Field pea plants have a shallow rooting system and have low tolerance to saline or water-logged soil conditions. The optimal soil pH for successful pea production is 5.5 to 7.0. Field peas are best grown in the Dark Brown and Black soil zones of Western Canada but they are also able to grow in the Brown soil zone (Figure 1.19, 1.20). They also need between 40 to 99 cm (16 to 39”) of moisture to achieve the best yields.[8]

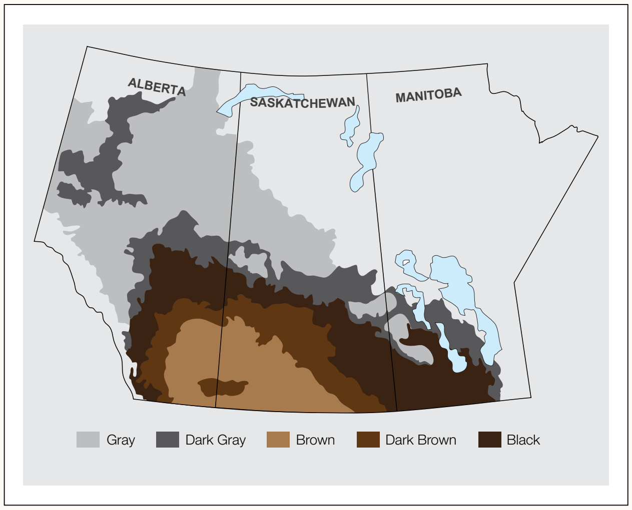


Figure 1.19. Western Canadian soil zones.
Source: Yan, W., Fetch, J. M., Fregeau-Reid, J., Rossnagel, B., and Ames, N. 2011. Genotype x location interaction patterns and testing strategies for oat in the Canadian Prairies. Crop Science Society of America. 51(5): 1903-1914.

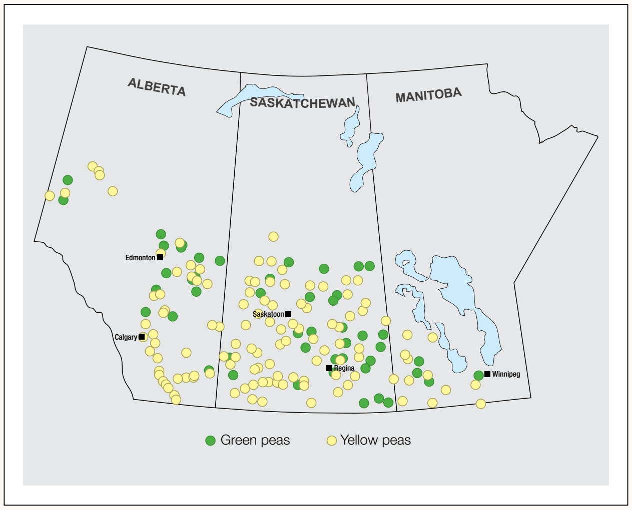


Figure 1.20. 2015 green and yellow pea growing regions.
Source: Wang, N. 2015. Quality of Western Canadian Lentils. Canadian Grain Commission.

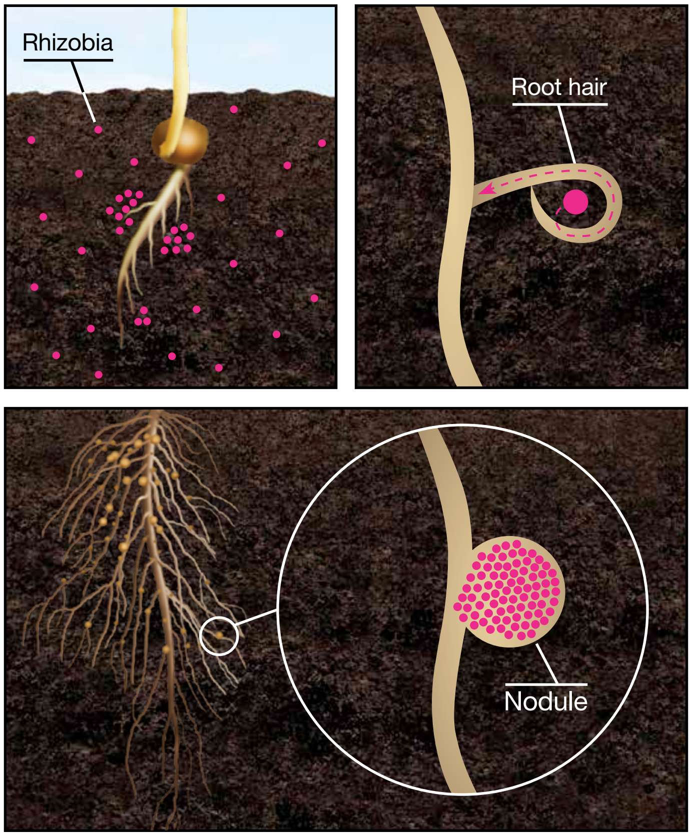
[8] Elzebroek, T., and Wind, K. 2008. Guide to cultivated plants. CAB International, Oxfordshire, UK.

Chapter 2 – Pre-seed decisions. Inoculants.

The use of inoculants is a vital part of any integrated management strategy for the successful establishment and improved yield potential of pulse crops. Inoculants enhance the unique and mutually beneficial relationship between pulse crops and nitrogen-fixing bacteria called rhizobia. The legume works together with the rhizobia to make nitrogen available for use by the plant (Figure 2.1). These rhizobia are located in nodules on the plant's roots and convert atmospheric nitrogen (N) into ammonium, a form that can be readily taken up by the crop. In return, the plant provides the rhizobia with energy, water and nutrients. Under ideal conditions, pulses can fix as much as 80% of their total required N.

Choosing an inoculant.

Inoculants are one of the most important inputs for pulse growers. They provide the plant with N which is essential for yield and protein production. Soils with a history of pulses may contain rhizobia, however they may not be present in sufficient numbers, they could be inefficient N fixers or they could be slow to colonize the roots leading to poor nodulation. Not all inoculants are made equal, so it's important to choose one from a reliable manufacturer who will guarantee a minimum rhizobial count.



Shortly after a legume germinates, the roots emit chemicals called flavonoids that attract rhizobia. The rhizobia are able to enter the root hairs and penetrate further into the root.

The rhizobia then respond by multiplying rapidly within the root hair and the plant responds by forming specialized structures called nodules. This process is called nodulation.

Figure 2.1. Rhizobia infection pathway.

Pick a strain specific to peas and lentils.

- Not all species/strains of beneficial rhizobia are the same in their efficiency for nodule formation and N fixation
- *Rhizobium leguminosarum* biovar *viceae* is the strain specific to peas and lentils
- Multi-strain inoculants are available, so ensure any inoculant you choose is specifically designed for peas or lentils
- If the wrong inoculant strain is used, no beneficial effect will be seen

Check label for 'minimum guaranteed analysis.'

- There is a minimum number of active rhizobia growers should start with
- Over time rhizobia die off, so it's key to start with the highest possible rhizobial levels
- Levels are represented in scientific notation, look for a high power of 10 (i.e. 10^8 or 10^9)
- All inoculant manufacturers should have this information available on their product labels

Choosing a formulation.

Inoculants are available in several different formulations – liquid, peat, granular and solid core granular. They all work effectively but there are some limitations with certain formulations.

- Liquid – Applied directly on seed, inexpensive, performance can be limited on virgin or very dry soils
- Peat – Applied on seed, most commonly used, inexpensive, contains non-toxic sticking agent (some restrictions with certain seed treatments)
- Granular – Primarily peat, applied in furrow, needs its own tank in the seeder (Figure 2.2)
- Solid core granular – Primarily clay granular, more expensive than all other options, more uniform size provides more uniform application (fewer skips and doubles) (Figure 2.2)

Figure 2.2. Solid core granules (left), peat granules (right).

Inoculant choice is farm specific and depends on seeder set up, field conditions and crop rotation history.

- Liquid kit for in-furrow liquid application
- Separate tank for granular and solid core granular inoculants
- On-farm seed treater required for liquid and peat inoculants

TIP

All inoculant formulations must be handled and stored differently than pesticides. Because they are living organisms, they are more sensitive to environmental extremes. Find more details next on how to properly handle these products.

Handling and storing inoculants.

Inoculants are living organisms and have specific storage and handling requirements to ensure viability.

Do:

- Keep cool, but not freezing (0 to 20°C)
- Keep dry
- Use before expiration date

Don't:

- Store next to pesticides and bulk fertilizers
- Store in direct sunlight and drying winds
- Stack more than 2 pallets high (granular only)

Compatibility with seed treatments.

- Every inoculant supplier will release the compatibility of their inoculant with seed treatments
- Always check seed treatment labels before application

Applying with fertilizers.

- Conduct soil tests annually or bi-annually to determine crop fertility needs
- Pulses use nitrogen (N) in the top 15 to 30 cm of the soil until N fixation begins
- When properly inoculated, fertilizer is typically not required
- If soil test shows inadequate N (< 11 kg/ha (10 lb/ac)), add starter fertilizer so combined available N is no more than 40 kg/ha (35 lb/ac)
- High levels of fertilizer (> 55 kg/ha (50 lb/ac)) can result in delayed nodulation and reduced N fixation
- Inoculants are sensitive to granular fertilizers
- Band fertilizer to the side or below the seed ensuring separation between rhizobia and fertilizer (allows time for the rhizobia to infect the root hairs and form nodule)
- Pulse crops require phosphorous (P) for plant development, nodule formation and N fixation

See Fertility, seeding and rolling (page 21) for more details.

Application methods.

Inoculants should be applied within 48 hours of seeding. This ensures a sufficient number of rhizobia will survive to infect the root hairs. It's important to check compatibility charts (available through the inoculant manufacturer) for on-seed survival times to ensure that re-inoculation is not required when seeding is delayed longer than expected.

In-furrow applications.

- Have a separate tank for inoculant
- Regularly inspect hoses and fittings for cracks and broken parts

- Calibrate for accurate metering (available on inoculant labels, technology sheets)
- Run fans to dry out tank before adding inoculants
- Fill no more than ½ the tank
- Run auger at 50% capacity or less
- Do not leave mixture in tank overnight

On-seed applications.

1) Tank mix – Mix products at the same time and apply on seed together (Figure 2.3)
2) Wet sequential (simultaneous) – Don't mix products but apply to seed at the same time (Figure 2.4)
3) Dry sequential – Apply seed treatment, allow to dry, apply inoculant (Figure 2.5)

Figure 2.3. Tank-mix application.

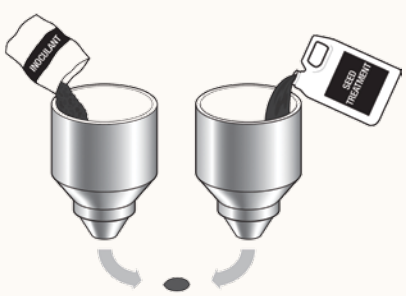


Figure 2.4. Wet-sequential application.

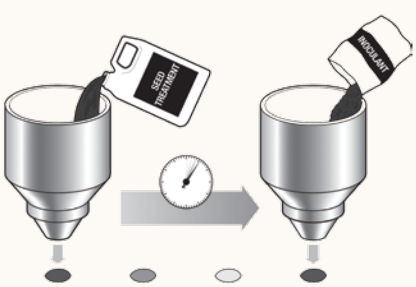


Figure 2.5. Dry-sequential application.

Choosing the correct application method.
Review the manufacturer's compatibility charts. Each formulation will have a rhizobial survival time when applied with a specific seed treatment using one of the methods stated above. The time required and product used will guide the application method you choose.

Evaluating nodulation.

So how can you tell if nodulation was successful? Nodule formation begins approximately three to four weeks after seeding. The number of nodules and the rate of fixation increases as the plant matures and normally reaches a maximum at the mid-flowering stage, coinciding with the stage at which the plant needs the most N.

How to check for nodulation.

- Carefully dig up plants from several areas in the field
- Wash or brush off soil – nodules can be easily brushed off, do this gently (Figure 2.6)
- On-seed inoculant – nodules will form on the primary root near the crown
- In-furrow inoculant – nodules will appear on secondary roots
- Nodules will appear as bumps along the tap root (main root) (Figure 2.7)
- Slice open the nodule
  - Red, peach or pink – effective nitrogen fixer (Figure 2.8)
  - Brown, beige or grey – non-effective nitrogen fixer
- Red colour is due to the presence of leghemoglobin, an iron-containing pigment necessary for fixation

TIPS

Order your inoculants early.
Because inoculants are living organisms, they can't be produced as far in advance as crop protection products. This gives manufacturers the opportunity to plan for the market demand and helps ensure the right amount is produced.

Storage, storage, storage.
Dead rhizobia won't help you achieve record-breaking yields. Do the best you can with the space you have to keep rhizobia in a cool, dry environment, away from direct sunlight. Do not stack granular inoculants or clumping may occur.

Figure 2.6. Checking for nodule formation.

Figure 2.7. Root nodule formation.

Figure 2.8. Healthy nodule, actively fixing nitrogen.
Source: Jennifer Dean, Penn State.

Seed testing and seed treatments.

To establish a profitable crop, you need an effective integrated management program. The first step is ensuring the seed is cleaned and tested for disease, germination, vigour, and trait retention (for **Clearfield**® lentil varieties). Combine this with the use of a fungicide seed treatment with multiple modes of action (MMOA), and you will be well on your way to paying dividends and protecting your investments.

Seedlings can **become infected** by:

- Seed-borne pathogens – Seeds produced by an infected plant
  - Ascochyta, Fusarium, and Botrytis
- Soil-borne pathogens – Via disease inoculum in infested crop residues
  - Pythium, Rhizoctonia, and Fusarium
- Plant-to-plant contact – Via another infected seedling

Seedlings can **spread infection** by:

- Infecting other plants by plant-to-plant contact
- Adding to the soil inoculum which leads to future infection

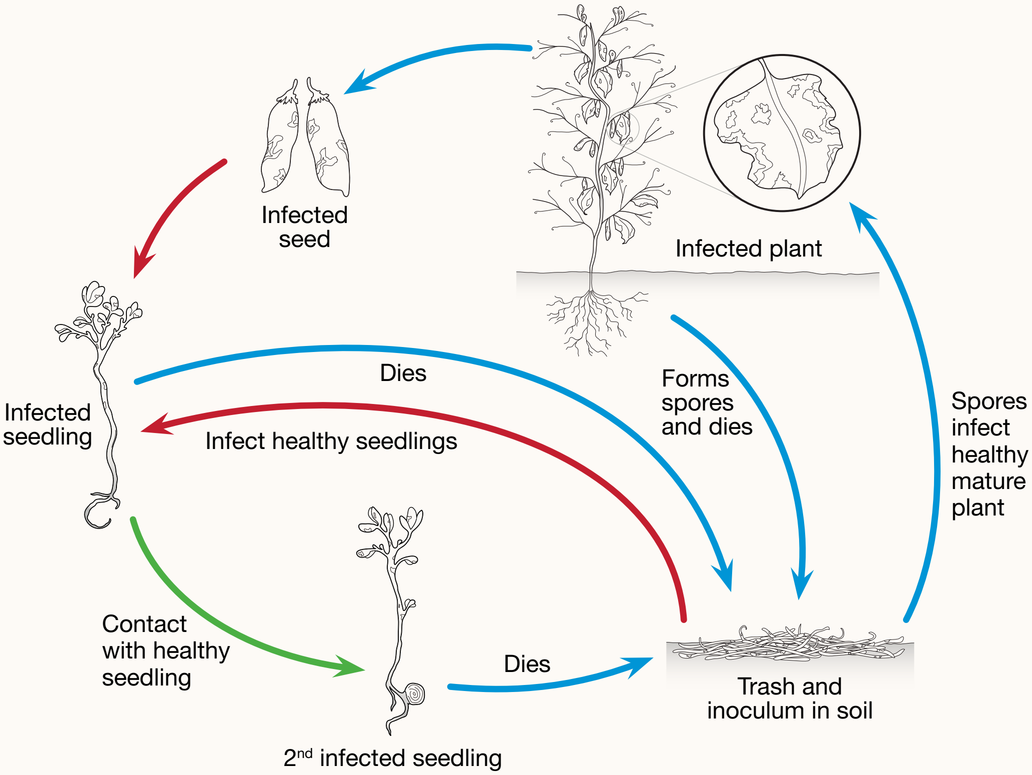


Figure 2.9. Seedling disease cycle.

Pathogen identification.

Seed and soil can both harbour numerous pathogens which can make identification of the fungal species difficult. Therefore, we usually refer to them by their clinical symptoms:

- Seed rot – Where the pathogen(s) present lead to death and decay of seed prior to germination and emergence
- Pre-emergence damping-off – Disease of seedlings, with infection occurring before emerging from soil. Characterized by rotting of stem at soil level and eventual collapse of plant
- Post-emergence damping-off – Disease of seedlings, with infection occurring after emergence. Characterized by rotting of stem at soil level and collapse of plant

Figure 2.10. Seedling blight and root rot.

- Seedling blight – Disease in which entire seedling becomes infected (to varying degrees) leading to reductions in plant stand. Also known as crown rot or foot rot (Figure 2.10)
- Root rot – Symptom or phase of many diseases, characterized by discolouration and decay of roots (Figure 2.10, 2.11)

The importance of seed testing.

One of the first things to consider at the end or beginning of the season, is testing the quality of your seed. Understanding where the seed stands in terms of germination, vigour and disease allows you to make more informed management decisions to achieve more even emergence and higher yields. High germination means plants will likely emerge more evenly, ensuring more even staging at herbicide and fungicide timing. Seed tests also determine 1,000 kernel weight which allows you to seed more accurately and establish the correct number of plants per acre.

Figure 2.11. Root rot.
Source: http://agdev.anr.udel.edu/weeklycropupdate/wp-content/uploads/2009/05/pearootrot.jpg

Seed cleaning.

The first step towards establishing a profitable crop is using clean seed. Seed cleaning ensures the removal of diseased or damaged seed and leads to improved quality. Diseased seeds may be shrunken or discoloured and can affect seed analysis. If seed is not cleaned, some seed labs will clean seed prior to testing which can affect the sample analysis.

What should you test for and why?

There are various seed testing packages available and you can discuss your options with your seed lab.

1. Germination.

- Measure of the percentage of seeds in a seed lot that are capable of germination under the best possible conditions

- Unlikely that you will be seeding under ideal conditions which is why testing seed vigour is also important

2. *Vigour (cold saturation test).*

- Determines the proportion of a seed lot that will be vigorous enough to germinate and survive the stresses associated with emergence
- Exposes the seed to increased water and reduced temperatures during germination
- Intention is to kill or hinder any seedlings that may be weak
- On average, an 8 to 10% reduction in germination is seen compared to a standard germination test

When choosing a seed lot, it is important to consider both germination and vigour results.

Interpreting your results.

Below are several examples of the kind of information or results you would typically find in your seed test analysis.

Seed Lot A – 95% Germination, 90% Vigour
Strong seed lot, can seed at the recommended rate and under all conditions.

Seed Lot B – 95% Germination, 80% Vigour
Average seed lot, ideally you would wait to sow into warmer soils or increase seeding rate to compensate for 20% reduction in vigour in cold soils.

Seed Lot C – 95% Germination, 60% Vigour
Best to sell this seed to a grain handler/elevator or if forced to use this seed, double the seeding rate and only sow into warm soils.

TIP
Try to avoid using the bottom 15 cm of any bin for seeding. It will have an extremely high number of damaged seeds from dropping out of the auger and onto the bin floor.

There is always a notes section on the seed analysis certificate which contains important information and should be read. Here are some examples of common notes:

1. *Abnormal and dead count.*

- How many dead seeds were present
- An abnormal seed initiates germination but will not produce a viable plant due to deficiency or physical damage

2. *Physical/Mechanical damage.*

- Some form of physical stress from harvest (augering, falling into a bin etc.) has damaged the seed

3. *Chemical damage.*

- Can occur if glyphosate is used prior to harvest
- Occurs if the plant is still cycling nutrients from roots to shoots
- End up with glyphosate being translocated into the seed
- Once planted, the glyphosate re-solubilizes and renders the seedling abnormal

4. *Potassium nitrate (KNO_3) levels.*

- KNO_3 is the chemical formula for the salt, potassium nitrate
- Potassium nitrate buffer is applied to seed to remove any dormancy still present within the seed
- This means that your samples were treated with this buffer to break dormancy

TIP

If you have used glyphosate to desiccate your crop, indicate this on your seed sample submission form. Your tests will be conducted in soil to avoid incorrect assessment.

5. *Physical purity.*

- Detects the amount of off-type grain present (i.e. weed seeds in lentil seed lot)
- Reported in the number of off-type seeds presented per kg of seed lot

Disease testing.

Certified seed only has to meet standards for germination and does not have to meet minimum disease standards. But planting clean seed avoids the introduction of disease. Correct diagnosis is key because diseases often occur as a complex so it's impossible to identify the diseases without proper testing. The diseases of economic importance for peas and lentils include ascochyta, anthracnose, botrytis, fusarium, mycosphaerella and sclerotinia. There are several reasons to conduct a disease test:

- Determines level of disease present in specific seed lot
- Used for CFIA certified analysis, the grading process and to determine if a seed lot should be saved for seed or not
- Levels of ascochyta and fusarium are strongly correlated to the number of seedlings that will be infected with seedling disease
- Botrytis can be present at low levels (e.g. 1.5 to 2%) but if the disease spreads after emergence, a single plant can infect an entire row

Below you'll find guidelines for acceptable disease levels for peas and lentils. It is important to take infection levels, germination and vigor into consideration when deciding whether or not to keep a seed lot.

Table 1. Disease threshold guidelines for on-seed pea and lentil diseases.

Disease	Crop	Disease Tolerance
Ascochyta	Field peas	Up to 15%
	Lentils	Up to 5%
Seed rots & damping-off (*Pythium* spp.)	Field peas Lentils	Soil-borne (not applicable)
Seed rots & seedling blights (*Botrytis* spp., *Rhizoctonia* spp., *Fusarium* spp.)	Field peas Lentils	Up to 10%
Anthracnose	Lentils	Soil-borne (not applicable)

Source: Adapted from guidelines provided by Discovery Seed Labs.

When to test your seed.

One of the most common questions is when to conduct a seed test. The answer is easy. As soon as it comes off of the combine. You will want to know if you should keep or sell the seed as soon as possible and seed testing helps you determine this. However, if you are not able to send a sample in during the fall, the quality of the seed typically does not change as a result of storage.

If your grain has not been stored under ideal conditions you should consider re-testing the seed for germination and vigour. For example, if the seed was placed in the bin with high moisture, warm winter temperatures or if the bin wasn't managed properly (not turned over, aerated or dried), it is highly likely that your fall test results are no longer relevant. Disease should not need to be retested but levels could change as a result of improper storage.

The importance of seed treatments.

Even if there is very little or no disease present in your seed lot, a seed treatment should still be considered to protect against soil-borne diseases. Seed treatments are a relatively minor expense that can greatly increase the profitability of your crop.

It's estimated that 53% of peas and 83% of lentils are treated with a fungicide seed treatment in Western Canada.

What to consider when choosing a seed treatment.

The primary factor when choosing a seed treatment is the seed- and soil-borne diseases of concern. However, other factors like ease of use can also be taken into consideration.

Figure 2.12. Field peas treated with a fungicide seed treatment (right) compared to untreated (left).
Source: BASF trials, St. Louis, SK, 2016.

Diseases controlled.

- Choose a seed treatment that controls the most economically impactful pathogens including ascochyta, anthracnose, rhizoctonia, fusarium, pythium and botrytis
- It should control a range of diseases caused by these pathogens such as seed rots, seedling blights, damping-off and root rots

Ease of use.

- Having a product that is ready to use can help save time and headaches
- Some products require the addition of water, while others need multiple products mixed together
- Ensure you know what formulation you are getting

Best practices.

- Always read the label to ensure proper rates are followed
- Check with the seed treatment manufacturers for seed treater calibrations to help ensure proper application and thorough coverage
- At the time of application, the seed temperature cannot be below -9°C as this can prevent the seed treatment from adhering to the seed
- Seed treatments should be stored above freezing to ensure proper viscosity. Ideal seed treatment storage temperature is between 0 and 30°C.
- Check with manufacturer for tank-mix guidelines and inoculant/insecticide compatibility
- Maintain proper auger speed to avoid plugging and maintain good coverage
- Dusting-off occurs with all seed treatments, but ensuring seed is clean and has been stored properly can help you avoid this

Fertility, seeding and rolling.

Soil fertility is an important part of establishing healthy and profitable pea and lentil crops. Having a comprehensive understanding of the dynamics of your soil fertility is critical to both short and long term success. Soil testing is a fantastic tool that allows you to understand the nutrients that need to be managed in a field, both in terms of cost and environmental factors. Nitrogen and phosphorus in particular are important for early crop growth and a correct balance will positively influence nodulation, nitrogen fixation and maturation.

Fertility guidelines.

Nitrogen (N).

- Ideal available N for peas and lentils at plant establishment is 28 to 40 kg/ha (25 to 35 lb/ac)[9]
- If soil test shows less than 22 kg/ha (20 lb/ac) of N, starter N should be added at around 10 to 15 kg/ha (9 to13 lb/ac) to bridge the 3 to 4 week gap before nodulation occurs

Phosphorus (P).

- Pulses typically require 22.5 kg/ha (20 lb/ac), field peas can require up to 40 to 54 kg/ha (36 to 48 lb/ac)
- Maximum application rate of seed-placed P is 17 kg/ha (15 lb/ac) in good or excellent moisture conditions

Potassium (K).

- Lentils: 84 kg/ha (75 lb/ac) of K is required for a 30 bu/ac yield
- Field peas: 138 to 168 kg/ha (123 to 150 lb/ac) of K is required for a 50 bu/ac yield
- Most soils have sufficient K, with exceptions in the Black or Grey soil zones of Northern Saskatchewan
- If soil contains less than 335 kg/ha (300 lb/ac) of K, approximately 22.5 kg/ha (20 lb/ac) should be applied
- It's essential that the combined amount of P and K do not exceed the recommended safe level, 17 kg/ha (15 lb/ac), for seed-placed P
- Even small amounts of seed-placed K can impact germination, so banding is ideal

Sulphur (S).

- To achieve a 40 bu/ac yield, pulses need 9 to 11 kg/ha (8 to 10 lb/ac) of S
- Do not exceed 20 to 26 kg/ha (18 to 23 lb/ac)

TIP

Due to the chemical nature of P, not all of the fertilizer that is placed in a given year will be used by the plants. If possible, provide P to fields the year before to supplement the following year's crop. For example, if a soil test reveals that only 9 kg/ha (8 lb/ac) of P is required to meet target, it would be wise to provide 17 kg/ha (15 lb/ac), as the extra will remain in the soil and be available to the following crop. Remember, it's critical to not exceed recommended rates because P can be hard on seed survival at high rates.

Lentils, and especially field peas, are sensitive to seed-placed fertilizer. Place fertilizer away from the seed, either side banded, mid-row banded, or apply prior to seeding. P can be safely used in furrow but should be restricted to less than 17 kg/ha (15 lb/ac) on field peas. Lentils are slightly more tolerant and can withstand up to 22.5 kg/ha (20 lb/ac) if there is sufficient moisture present.[10]

TIP
Lentils and peas have good frost tolerance. Even if frost is severe enough to kill the main shoot they can regrow from one or both of the scale nodes. The scale nodes are typically found below the soil surface. Peas and lentils routinely survive frosts of -7°C.

Seeding.

Peas and lentils need to be seeded early to take advantage of available moisture or as soon as the soil temperature is 5°C or greater. In Western Canada this is generally between mid-April and early- to mid-May.

Why?

- Field peas and lentils need roughly an inch of moist soil to germinate due to the amount of imbibition that occurs
- Peas need 3 times more water than cereal grains to germinate
- Seeding earlier also reduces the chances of flower blast since plants typically flower when it's cooler
- This may increase the height of the plant, helping to keep the lowest pods higher off the ground for an easier harvest

Seeding depth.

Field peas – 3 to 8 cm
Lentils – 2.5 to 7.5 cm

Seeding equipment tips.
Any type of seeder will work for seeding lentils. Whichever type of seeding equipment is used, it is important to calibrate it with inoculated seed because inoculants can add drag to the flow rate.[11]

When using an air seeder, caution should be taken to prevent damage to the seed. Cracking and chipping can occur if air velocity is too high or if the seed is very dry. Use the lowest fan speed possible that still permits seed movement. Water can be added to moisturize the seed to lessen damage through handling and seeding if needed (see PAMI Research Update #704).

TIP
The deeper you seed your pulse crop, the longer it will take to emerge. If you're seeding below 5 cm, regardless of temperature and moisture conditions, a seed treatment should be used to protect the fragile seedling as it pushes through the soil.

[9] Pea Production Manual. Saskatchewan Pulse Growers.

[10] Saskatchewan Pulse Growers. 2016. Saskatchewan Pulse Crops: Seeding and Variety Guide, p. 05 (Dr. Jeff Schoenau).

[11] Government of Saskatchewan, 2016.

TIP

To determine how deep to plant the seed, place your thermometer in the soil. Take two measurements throughout the day: one in the morning and one in the early evening. Average the two readings to determine average soil temperature at the depth of seeding. Take readings in a number of locations in the field, especially if the field is rolling and variable.[11]

Seeding rates.

Using appropriate seeding rates can result in more even maturity, better weed control with more competition from the crop and higher yields.

It's important to acquire optimal (target) crop densities. Each crop has a range of densities and after an initial rapid increase in yield with increasing plant density, there is a plateau of maximum yield over a broad range of plant densities. At very high densities, yield begins to decline (Figure 2.13).

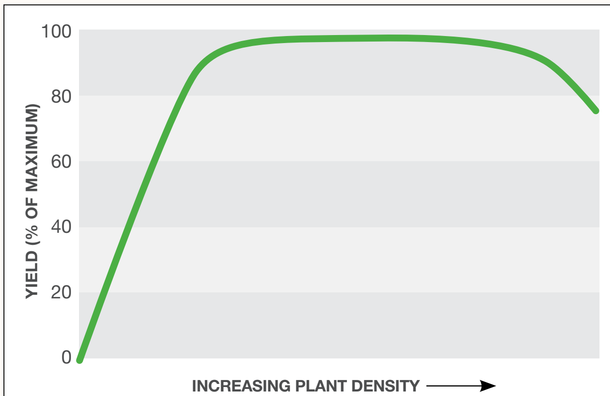


Figure 2.13. The crop yield and plant density relationship follows a pattern.
Source: Alberta Agriculture and Food 2007.

There are 3 things required to determine optimal seeding rates:

1. Targeted plant population
2. 1,000 kernel weight
3. Seedling survival rate

1. Targeted plant population.

Lentils

- Target plant stand = 130 plants/m^2 or 12/ft^2

Field peas

- Target plant stand = 75 to 85 plants/m^2 or 7 to 8 plants/ft^2
- Early seeded or conventional tall varieties grow best at lower densities (75 plants/m^2)
- Later seeded or semi-leafless varieties grow best at higher densities (85 plants/m^2)

TIP

Don't overthink seeding rates.
This information will help you, but trying different seeding rates can provide a better understanding of what works best for a particular field.

2. 1,000 kernel weight (TKW or TSW).

Thousand kernel or seed weight (TKW or TSW) is a measure of seed size. It is the weight in grams of 1,000 seeds. This varies from crop to crop and even between varieties of the same crop.

[11] Government of Saskatchewan, 2016.

> **TIP**
> When testing seed for vigour, germination and disease, the seed lab can determine the 1,000 kernel weight of the seed lot.

3. Seedling survival rate.

This is the hardest to calculate because a number of factors contribute to seedling survival. A good estimate is 5 to 20% less than your germination rate but it may increase or decrease based on field conditions, seeding date and weed pressure.

You should increase or decrease seeding rates depending on:

- Weed populations – high weed pressure = increase seeding rate
- Field conditions – more moisture = increase seeding rate

Once target plant population, TKW and seedling survival percentage have been determined, your seeding rate can be calculated. The Government of Alberta has a seeding rate calculator which can be found on their website[12], or alternatively, you can use the following.

Seeding rate (kg/ha) = target plant population/m^2 x TKW (g) ÷ seedling survival rate*

To convert to lb/ac, multiply kg/ha seeding rate by 0.89, or use the equation below:

Seeding rate (lb/ac) = target plant population/ft^2 x TKW (g) ÷ seedling survival rate* ÷ 10.4

*In decimal form i.e. 80% = 0.80

Example for field peas with 80% seed survival:
Seeding rate (lb/ac) = 8 plants/ft^2 x 200 g ÷ 0.8 ÷ 10.4 = 192 lb/ac

Row spacing.

Narrower spacing between plant rows allows for faster canopy closure to reduce soil moisture loss. Wider spacing decreases yield and competitiveness, especially for lentils which are already poor competitors.[13]

Lentils – 20 cm row spacing is ideal for high yield potential
Field peas – 15 to 30 cm row spacing is ideal for high yield potential

Be aware that row spaces wider than the guidelines stated above can lead to lodging. For pulse crops in no-till systems, it is best to seed in inter-row spacing from previous crop.

[12] Alberta Government – Seeding rate calculator for peas, pulses and other large seeds [https://www.agric.gov.ab.ca/app19/calc/crop/otherseedcalculator.jsp].

[13] Saskatchewan Pulse Growers. 2000. Pulse Production Manual 2000.

Figure 2.14. Seed roller.

Rolling.

Rolling helps provide better seed-to-soil contact, a smooth surface with fewer rocks for harvest efficiency and it allows the cutter bar to get closer to the base of the plants, helping to preserve yield (Figure 2.14).

Rolling can be done any time after seeding up to the 7th node stage in peas and lentils with a light to medium weight roller. Rolling beyond the 7th node stage can damage stems and impact yield. If the field has significant residue, which is common in no-till systems, it is recommended to roll closer to seeding. If there is limited residue, waiting until plants are established can help reduce erosion.

Roll on warmer days because the slight wilting in plants will make them more flexible and therefore less prone to breakage. Avoid rolling immediately after any stress to the plants, such as a frost event or herbicide application. Instead, allow a couple of days for recovery before proceeding. If possible, also avoid rolling in damp conditions as it can sometimes increase compaction and the spread of seedling diseases throughout the field.

TIP

If pre-emergence rolling was missed and you have to choose between spraying a herbicide or rolling, always spray. The yield loss due to an unmanaged weed population far outweigh the yield loss from not rolling.

Chapter 3 – Weed management.

To get a good idea of the amount and type of weeds present in your field, scout the entire field in a W pattern (Figure 3.1), taking weed counts at a minimum of 20 points throughout. Being aware of any new or herbicide-resistant weeds present in the field will help growers make effective management decisions before the problem escalates. Constructing a field map can be useful to monitor success of control methods, spread of weeds and it provides a reference point for future crop years.

When considering herbicide usage on a field, it is recommended to delay the development of resistance by implementing a 1-in-3-year herbicide rotation.[14] If herbicide applications are avoided in a particular season, it provides a greater variety of active ingredients to choose from the following season. However, deciding not to spray because weed pressure is low will only increase the severity of the problem the next year. The weeds present that year will be able to set and disperse seed and essentially multiply the potential number of weeds.

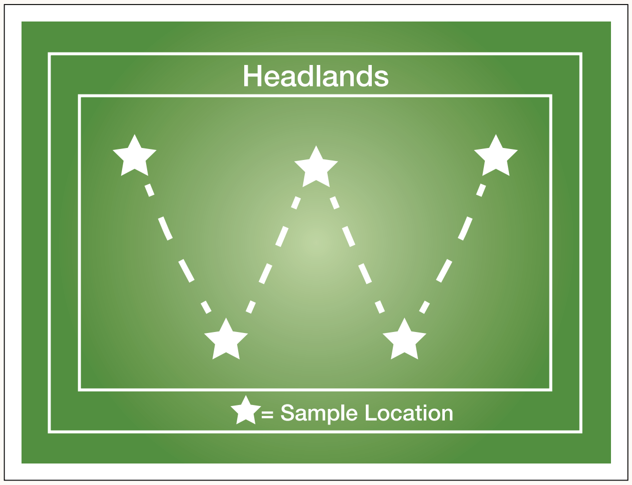


Figure 3.1. Collect samples at each point of the W.

Before spraying a herbicide it's important to take into consideration:

- Weeds present and the product(s) that will be effective against them
- Timing of the application and the growth stage of the weeds
- Appropriate rate for the field location and soil type
- History of herbicides previously used on the field

The economic threshold is another factor that will affect your spray decisions. This is the level at which the financial cost from yield loss due to weed infestation is greater than the cost of herbicide application. Whenever the economic threshold is exceeded, spraying is the most favourable option from a cost perspective. While some producers may consider this to be a deal breaker, it is important to consider it more as a guideline. This is because the yield loss from weeds may not appear to make spraying worth it, but dockage and downgrading from weed seeds and material may also impact the crop return. Applying a herbicide may be more financially favourable at a lower economic threshold than calculated solely from yield loss from weed competition.

[14] Government of Saskatchewan. 2016. 2016 Guide to Crop Protection: For the chemical management of weeds, plant diseases and insects.

Key weeds.

In Western Canada, there are a variety of grassy and broadleaf weeds that pose significant problems in lentils, peas and other pulse crops. If weeds become established and are not managed correctly, yield losses of up to 75% can occur, especially since both peas and lentils are poor competitors.

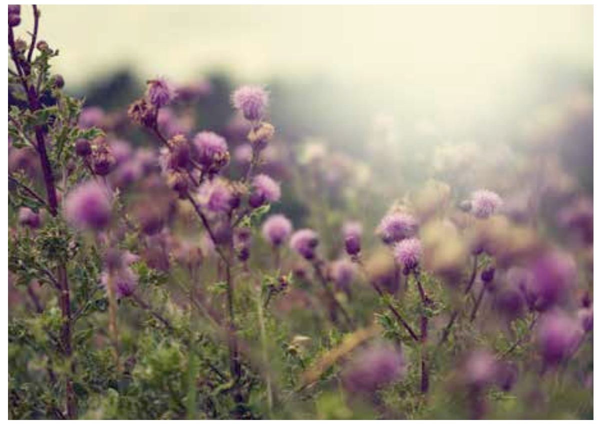
Common weeds that threaten pulse production in Western Canada include:

Table 2. Common weeds in Western Canada.

Broadleaf Weeds	Grassy Weeds
Canada thistle	Barnyard grass
Chickweed	Downey brome
Cleavers	Fall panicum
Cocklebur	Foxtail barley
Dandelion	Green and yellow foxtail
Flixweed	Japanese brome
Hairy nightshade	Persian darnel
Hemp-nettle	Proso millet
Kochia	Quackgrass
Lamb's quarters	Volunteer barley
Narrow-leaved hawk's beard	Volunteer canary seed
Night-flowering catchfly	Volunteer tame oat
Perennial sow thistle	Volunteer wheat
Redroot pigweed	Wild millet
Round-leaved mallow	Wild oat
Russian thistle	Witchgrass
Scentless chamomile	
Shepherd's purse	
Smartweed	
Stinkweed	
Stork's bill	
Volunteer canola	
Volunteer tame mustard	
Wild tomato	
Wild buckwheat	
Wild mustard	

Cultural practices.

There are several cultural practices that growers can implement to enhance their ability to combat weed pressure. These include crop rotation and making informed field selection decisions. In the year prior to seeding pulses, avoid allowing weeds to reach seed set as this will only make weed management more difficult. Fields where dandelion, Canadian thistle and perennial sow thistle were previously present in high numbers should be avoided because there are no in-crop control options for these broadleaf weeds.



A useful method to lower weed pressure includes selecting lentil and pea varieties that are best suited for the growing area to increase the likelihood of a thriving crop. Seeding at the optimal depth, rate and spacing also helps to ensure growers are producing a healthy and well established crop (Figure 3.2). Additionally, providing the proper fertilization, inoculating your crop and managing insects and diseases can also help maintain a strong plant stand.

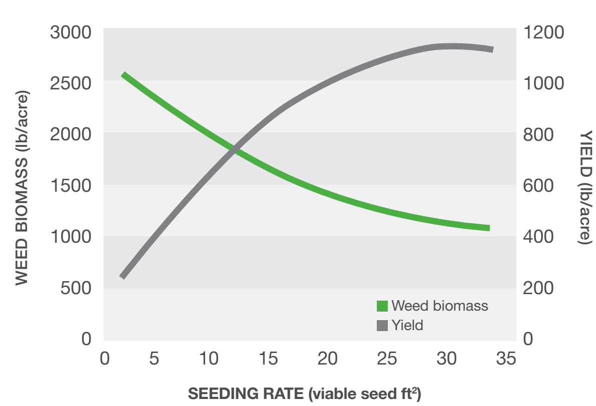


Figure 3.2. Lentil seeding rate effect on weeds and yield. Source: Adapted from Menalled, F. 2009. Integrated Weed Management in Lentils. Montana State University Extension.

Figure 3.3. Tine harrow implement for mechanical control of weeds in pulse crops.

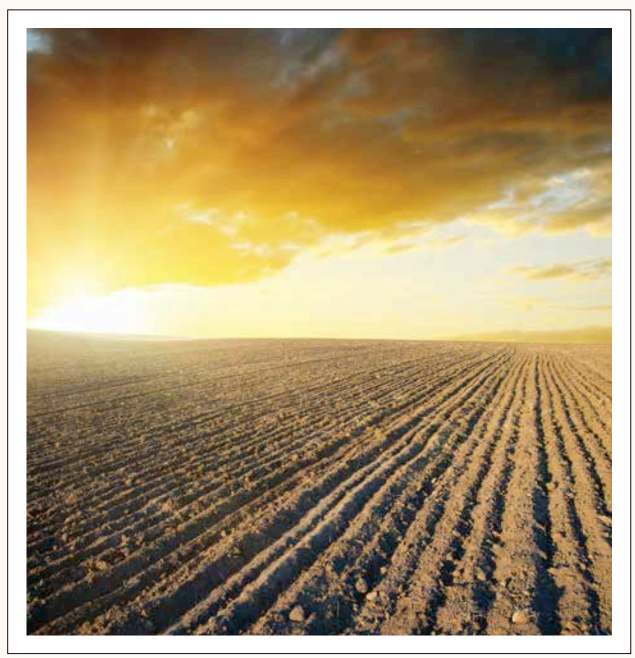
Integrated weed management.

Cultural and mechanical control methods should be combined with herbicide use for a well-rounded integrated weed management plan. Mechanical methods for weed removal involve practices like tine harrowing (Figure 3.3) which can be done up to the seedling stage (10 cm) in lentils. Tine harrowing should only be conducted when the leaves are dry. To facilitate desiccation of the weeds, it's best done on sunny days.[15] It is recommended to use a higher seeding rate to compensate for the minor plant losses that will occur.

Be sure to take the full crop rotation into consideration when creating a weed management program, especially if perennial weeds were a concern in previous years.[15] Apply a herbicide in the fall to control winter weeds and to reduce any residue carryover from impacting the crop.

Implementing an integrated weed management program can help reduce herbicide use and decrease or prolong the development of resistant weeds.

When planning for herbicide use, growers should be aware of potential residue buildup in the soil because this effects which crops can be grown in the following years. Understanding these factors will help growers make smart herbicide choices and prevent any impact on rotational crop plans.



[15] Saskatchewan Pulse Growers. 2000. Pulse Production Manual 2000.

Weed management with herbicides.

Contact herbicides – Cause rapid dry down when they come in contact with plant tissue.
Systemic herbicides – Are translocated to growing points of the plant where natural senescence then occurs.

Herbicides can have systemic activity, contact activity or both. They're also separated by group based on their mode of action (MOA). The various groups and their respective modes of action are listed in Table 3. Weed species that are problematic in pulse crops and have demonstrated resistance in Western Canada are shown in Table 4.

Keep in mind that in other parts of Canada and bordering states of the USA, the weeds listed in Table 4 are resistant to additional herbicide groups. These could develop in the prairie provinces if herbicides are not managed correctly.

It's also important to be aware of the herbicide groups you are using since new herbicides often don't have new modes of action and instead are new combinations of the 18 groups listed in Table 3. More information can be found in government crop protection guides and product labels.

Remember, all herbicide products have different instructions for application timing and limitations concerning the amount of organic matter in the soil, soil type, moisture levels, and soil pH. Government crop protection guides and product labels must be consulted before application of any herbicide.

Table 3. Herbicide Groups MOA.

Mode of Action	Group		
Systemic	1	2	3
	4	9	11
	15	19	20
	26		27
Contact	6	10	22
Systemic & Contact	5	7	8
	14		

Table 4. Herbicide-resistant weeds in Western Canada.

Resistant Weed	Herbicide Group
Ball mustard	2
Chickweed	2
Cleavers	2, 4 Combinations of 2 & 4
Cow cockle	2
Green foxtail	1, 2, 3 Combinations of 1 & 3
Hemp-nettle	2, 4
Kochia	2, 4, 9 Combinations of 2 & 9 Combinations of 2 & 4
Lamb's quarters	2
Narrow-leaved hawk's beard	2
Persian darnel	1
Powell amaranth	2
Redroot pigweed	2
Russian thistle	2
Shepherd's purse	2
Smartweed	2
Spiny sowthistle	2
Stinkweed	2
Wild buckwheat	2
Wild mustard	2, 4, 5
Wild oat	1, 2, 8 Combinations of 1 & 2 Combinations of 1 & 8 Combinations of 2 & 8 Combinations of 1, 2 & 8 Combinations of 1, 2 & 25 Combinations of 1, 2, 8 & 25 Combinations of 1, 2, 8, 14 & 15

Source: Adapted from the 2016 Crop Protection Guide, Government of Saskatchewan and Heap, I. The International Survey of Herbicide Resistant Weeds. Available www.weedscience.org

Post-harvest weed control – Prior to seeding.

There are several weed control options that can be utilized following harvest and before seeding lentils or peas the following spring. Always be sure to read and follow label directions before making any application.

Applying 2,4-D and MCPA in the fall to control weeds prior to seeding lentils is a common, low-cost and effective method of weed control. However, there is a high risk of residue carryover which can cause crop injury, especially in cool, dry environments. The risk is slightly reduced when salt or amine formulations of 2,4-D and MCPA are used as opposed to the ester versions. In general, MCPA is lower risk compared to 2,4-D.[15] The use of these products has decreased in recent years due to the development of new products with new modes of action and better residual control.

Fall applications of trifluralin or ethalfluralin (Group 3) products prior to seeding lentils and peas in the spring are recognized as acceptable for use. Incorporation (tillage) is required in the fall and seed should not be placed deeper than 4 cm. These two actives may also be used in field peas in the spring, prior to seeding.

Dicamba (Group 4) and diflufenzopyr (Group 19) can be applied post-harvest in the fall before growing lentils or peas, but only if it's sprayed before October 1st. Be sure to double check the label to ensure your dicamba herbicide is appropriate for post-harvest.

Pre-seed and pre-emergent weed control.

Pre-seed weed control is recommended before seeding any crop and there are a few management options available when it comes to pre-seed pea and lentil herbicides (See Table 6 on page 33 for pre-seed herbicide comparison).

1. *Flumioxazin* (Group 14).

This herbicide can be applied post-harvest before freezing, in the spring prior to seeding and up to three days after seeding, before emergence. It can be applied in field peas but not in lentils. It can control broadleaf weeds emerging from seed but it's not effective if the weeds have already emerged at the time of application.

2. *Sulfentrazone* (Group 14).

This herbicide can also be applied prior to seeding or up to three days after seeding in field peas. Lentils can only be grown two winters after sulfentrazone use.

3. *Carfentrazone* (Group 14).

This is a viable option for pre-seed weed control in lentils and field peas. It can also be used in combination with other active ingredients such as glyphosate (Group 9) and sulfentrazone (Group 14) to provide an additional mode of action against certain broadleaf weeds.

4. *Saflufenacil* (granule or liquid, Group 14).

This herbicide must be used in combination with glyphosate (Group 9) for pre-seed or pre-emergent weed control in lentils and peas. It is effective against many broadleaf weed species. When used at the high rate in peas, it provides residual activity to suppress key flushing weeds.

5. *Glyphosate* (Group 9).

Because of the overuse of glyphosate in crop production, it is not recommended to use it alone to manage pre-seed or pre-emergent weeds. Several weeds have already developed resistance to glyphosate and more instances will occur if resistance management strategies are not followed.

15 Saskatchewan Pulse Growers. 2000. Pulse Production Manual 2000

Post-emergent weed control.

Given that peas and lentils are both very non-competitive crops, ensuring early removal of weeds is essential to preserving the yield potential of the crop. Many crops have a critical period of weed control or the time at which weeds must be removed to achieve maximum yield. In field peas, this timing is between emergence to the 6th node stage (Figure 3.4). With lentils, the critical weed control period begins at the 5th node stage and continues until the 9th node stage (Figure 3.5).

The node stage of the crop is also very important when considering in-crop weed control with herbicides. Injury may occur if the field is sprayed outside of the recommended timing (stage).

It is also essential to keep in mind which herbicide active ingredient is being used to help mitigate the risk of resistant weeds. With the prevalence of Group 2 resistance, it is recommended that Group 2 products only be used a maximum of two times in a four-year period and never twice in the same year. Where possible, this is also a good guideline for all herbicide groups for resistance management.

Choosing a herbicide.

Conventional lentils.

Lentils are sensitive to most herbicides and this presents a few challenges when it comes to post-emergent broadleaf and grassy weed control. All post-emergent herbicides are best applied when plants are small in size to reduce the risk of injury to the crop and enhance the effectiveness of the product on the weeds. The limited options for weed control in conventional lentils include: metribuzin (Group 5) for control of broadleaf weeds and quizalofop (Group 1), sethoxydim (Group 1) and clethodim (Group 1) for grassy weeds.

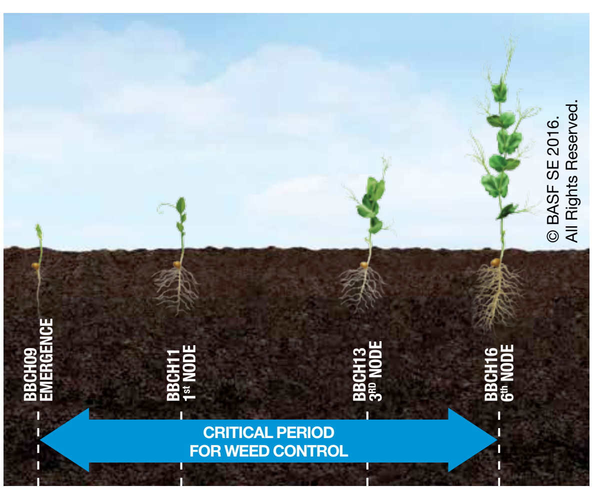


Figure 3.4. Critical period for weed control in field peas.

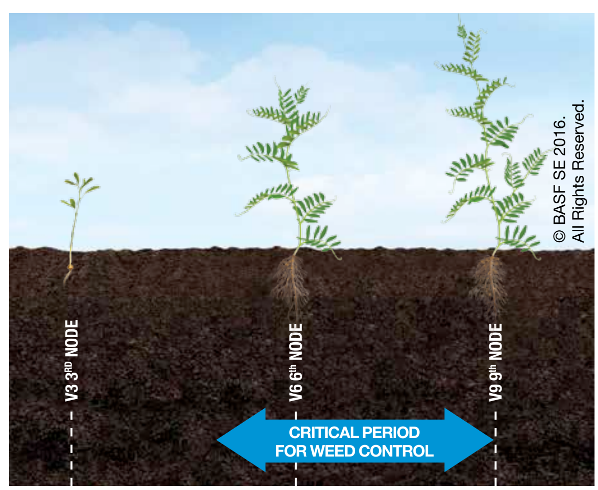


Figure 3.5. Critical period for weed control in lentils.

***Clearfield** lentils.*

The introduction of the **Clearfield** Production System for lentils has provided an effective solution for in-crop weed control. Imazamox, imazethapyr, and imazapyr (all Group 2) can all be used for in-crop weed control in **Clearfield** lentils (See Table 7 on page 33 and 34 for in-crop herbicides for **Clearfield** lentils). However, all herbicides registered for use on conventional lentils can also be used on **Clearfield** lentils.

Field peas.

According to the Guide to Crop Protection developed by the Saskatchewan Ministry of Agriculture, there are several active ingredients from a variety of herbicide groups that are effective on different broadleaf and grassy weeds in field peas (See Table 5). Please refer to the guide to learn more.

Crop injury – Prevention and diagnosis.

Pre-seed herbicide applications are generally recognized as a more ideal option compared to in-crop/post-emergent applications. If a post-emergent application is necessary, take a look at the following tips to reduce the likelihood of crop injury:

- Check variety tolerances
- Avoid applying herbicide to dry soils[16]
- Apply only at recommended plant stage – if there is a range, aim for the earlier stage
- Do not spray when crop is stressed – wait 4 days before spraying
- Try to spray in evening – temperatures tend to be lower than mid-day or morning
- Use the recommended water volume or an increased water volume
- Ensure tank is well cleaned before filling with herbicide for lentil or pea application
- Follow wind speed recommendations – helps prevent drift from damaging pulses

Table 5. Herbicides for post-emergent weed control in field peas.

Group	Active Ingredient	Target Species
1	Clethodim Quizalofop Sethoxydim	Grassy weeds
2	Imazamox Imazethapyr	Grassy weeds Broadleaf weeds
4	MCPA amine*	Broadleaf weeds
5	Metribuzin	Broadleaf weeds
6	Bentazon	Broadleaf weeds

*Crop injury to field peas is likely when using MCPA, only amine formulation is acceptable, lower than maximum label rate recommended to lessen injury.
Source: Guide to Crop Protection, Saskatchewan Ministry of Agriculture.

16 Pulse Australia 2015. Best Management Guide Lentil Production: Southern Region. http://www.pulseaus.com.au/growing-pulses/bmp/lentil/southern-guide#weed-management

Table 6. Pre-seed herbicides in pea and lentil crops.

	Heat® LQ (30 ac/case)	Heat LQ (80 ac/case)	Authority® (FMC)	Authority Charge (FMC)	GoldWing®	Focus®	Valtera™	Edge® (Gowan)	Express® SG (DuPont)
Active ingredient(s)	Saflufenacil	Saflufenacil	Sulfentrazone	Sulfentrazone + Carfentrazone (AIM)	Pyroflufen + MCPA	Carfentrazone (AIM) + Pyroxasulfone	Flumioxazin	Ethalfluralin	Tribenuron-methyl
Group(s)	14	14	14	14	14, 4	14, 15	14	3	2
Pulse crop(s)	Field Peas	Field Peas Lentils	Field Peas	Field Peas	Field Peas	Not registered – submitted for peas and lentils in 2017	Field Peas	Field Peas Lentils (Fall application only)	Field Peas
Contact / Systemic	Contact Systemic	Contact Systemic	N/A	Contact	Contact Systemic	Contact	Systemic	Systemic	Systemic
Foliar weed control	Y	Y	N	Y	Y	N	N	N	Y
Residual weed control	Y	N	Y	Y	N	Y	Y	Y	N
Moisture required for activation	¼"	N/A	½"	½"	N/A	½"	¼ – ½"	Incorporation	N/A
Key herbicide resistant weeds on label									
Volunteer canola	C + Residual	C			S	S	S		C
Cleavers	C + Residual	C	Residual	Residual	C	Residual		S	
Kochia	C	C	Residual	Residual	C	S	Residual	Residual	
Wild buckwheat	C + Residual	C	Residual	Residual	S			Residual	C
Redroot pigweed	C + Residual	C	Residual	C + Residual	C	C + Residual	Residual	Residual	C
Stinkweed	C + Residual	C			C	Residual			
Wild mustard	C + Residual	C			S				C
Lamb's quarters	C	C	Residual	C + Residual	C	C + Residual	Residual	Residual	C

C – Foliar Control S – Suppression

Table 7. Compatible in-crop herbicides for **Clearfield** lentils.

Products	Ares®	Solo® ADV	Solo Ultra	Odyssey® Ultra NXT	Odyssey NXT
I need	Powerful control of tough broadleaf weeds, including lamb's quarters, wild buckwheat, cleavers and volunteer canola.	Excellent re-cropping flexibility the following year plus the convenience of a liquid formulation.	Exceptional re-cropping flexibility with the wide-spectrum grass control of Poast® Ultra.	Targeted control of broadleaf weeds with wide-spectrum grass control of Poast Ultra.	The same performance of Odyssey, conveniently packaged in jug containers with Merge® adjuvant.
Active ingredients	Imazamox – Group 2	Imazamox – Group 2	(a) Imazamox – Group 2	(a) Imazamox – Group 2	Imazamox – Group 2
	Imazapyr – Group 2	—	(b) Sethoxydim – Group 1	(a) Imazethapyr – Group 2	Imazethapyr – Group 2
	—	—	—	(b) Sethoxydim – Group 1	—
Merge	Included in case	Built-in		Included in case	
Formulation	Liquid concentrate	Solution	(a) Liquid solution (b) Liquid emulsifiable concentrate	(a) Water dispersible granules (b) Emulsifiable concentrate	Water dispersible granular
One case contains (40 ac/case)	9.8 L jug Ares 8.1 L jug Merge adjuvant	2 x 6.5 L jugs or 3 x 4.33 L jugs	(a) 2 x 6.5 L jugs Solo ADV (b) 6.16 L jug Poast Ultra	(a) 692 g jug (b) 6.16 L jug 8.1 L jug Merge adjuvant	2 x 692 g jugs Odyssey NXT 2 x 8.1 L jugs Merge adjuvant
Lentil staging	1 to 9 node **Clearfield** lentils only				

Table 7. In-crop herbicides for **Clearfield** lentils, continued.

Products	Ares	Solo ADV	Solo Ultra	Odyssey Ultra NXT	Odyssey NXT
Broadleaf weeds controlled	Apply at cotyledon to 4 leaf (except where indicated)				
	Chickweed[1] Cleavers[1] (1 to 4 whorls) Cow cockle Green smartweed Hemp-nettle Lamb's quarters (cotyledon to 6 leaf) Redroot pigweed[1] Round-leaved mallow Russian thistle Shepherd's purse[1] Stinkweed[1] Stork's-bill[1] Volunteer canola[1,2] Volunteer tame mustard Wild buckwheat (cotyledon to 6 leaf) Wild mustard[1]	Cleavers[5] (1 to 4 whorls) Cow cockle Green smartweed Lamb's quarters Redroot pigweed Round-leaved mallow[5] Russian thistle Shepherd's purse Stinkweed Volunteer canola[2] Wild buckwheat[5] Wild mustard	Cleavers[5] (1 to 4 whorls) Cow cockle Green smartweed[6] Lamb's quarters Redroot pigweed Round-leaved mallow[5] Russian thistle Shepherd's purse Stinkweed Volunteer canola[2] Wild buckwheat[5] Wild mustard	Chickweed Cleavers Flixweed Green smartweed Hemp-nettle[7] Lamb's quarters[5] Redroot pigweed Russian thistle[7] Shepherd's purse Stinkweed Stork's-bill Volunteer canola[2] Volunteer tame mustard Wild buckwheat[7] Wild mustard	Chickweed Cleavers (4 whorls) Flixweed Green smartweed Hemp-nettle[5] Lamb's quarters[5] Redroot pigweed Russian thistle[5] Shepherd's purse Stinkweed Stork's-bill Volunteer canola[2] Volunteer tame mustard Wild buckwheat[5] Wild mustard
Grasses controlled	Apply at 1 to 6 leaf (except where indicated)	Apply at 1 to 4 true leaf up until early tillering		Apply at 1 to 6 true leaf or up to 2 tillers (except where indicated)	Apply at 1 to 4 true leaf
	Barnyard grass Green foxtail[1] Persian darnel Spring germinating Japanese brome grass (1 to 4 leaf) Volunteer barley Volunteer canary seed Volunteer durum wheat Volunteer spring wheat[3] Volunteer tame oats Wild oats Yellow foxtail	Barnyard grass Green foxtail Japanese brome grass[5] Persian darnel Volunteer barley Volunteer canary seed Volunteer durum wheat Volunteer spring wheat[2] Volunteer tame oats Wild oats Yellow foxtail	Barnyard grass Crabgrass Fall panicum Green foxtail Japanese brome grass[5] Persian darnel Proso millet Quackgrass[5] Volunteer barley Volunteer canary seed Volunteer corn Volunteer durum wheat Volunteer spring wheat[4] Volunteer tame oats Wild oats[6] Witchgrass Yellow foxtail	Barnyard grass Crabgrass (large) Fall panicum Green foxtail[6] Japanese brome grass[8] Persian darnel Proso millet Quackgrass[8] (2 to 5 leaf) Volunteer barley Volunteer corn Volunteer tame oats Volunteer wheat[4] Wild oats[6] Witchgrass Yellow foxtail	Barnyard grass Green foxtail Persian darnel Volunteer barley Volunteer tame oats Volunteer wheat Wild oats
Follow crops	**3 months after application**				
	—	Winter wheat	—	—	—
	1 year after application				
	Canary seed Chickpeas Field peas Field corn **Clearfield** canola **Clearfield** canola quality *Brassica juncea* Lentils[4] Spring wheat[4] Spring barley Tame oats	Canary seed Canola[4] Chickpeas Durum wheat Field corn Field peas Flax Lentils[4] Soybeans Spring barley Spring wheat[4] Sunflowers[4] Tame oats	Canary seed Canola[4] Chickpeas Durum wheat Field corn Field peas Flax Lentils[4] Soybeans Spring barley Spring wheat Sunflowers[4] Tame oats	Canary seed Chickpeas **Clearfield** canola Durum wheat Field corn Field peas Lentils[4] Spring barley Spring wheat Tame oats	Barley Canary seed Chickpeas **Clearfield** canola **Clearfield** canola quality *Brassica juncea* Durum wheat Field corn Field peas Lentils[4] Spring barley Spring wheat Tame oats
	2 years after application				
	Durum wheat Flax Non-**Clearfield** canola Sunflower	Mustard (condiment-type only)	Mustard (condiment-type only)	Flax Non-**Clearfield** canola Sunflowers	Flax Non-**Clearfield** canola Sunflower

Note: Odyssey Ultra NXT and Odyssey NXT herbicides can also be applied in field peas at the 1 to 6 true leaf stage.

[1] Multiple flushing weeds. [2] Non-**Clearfield** varieties only. [3] Non-imazamox tolerant varieties only. [4] Including **Clearfield** varieties. [5] Suppression only. [6] Including Group 1-resistant biotypes and Group 2-resistant biotypes. Will not control biotypes that have multiple resistance to both Group 1 and 2 herbicides. [7] Suppression in **Clearfield** lentils. [8] Odyssey Ultra NXT herbicide will provide control of spring germinating Japanese brome grass and suppression of fall emerged Japanese brome grass.

Chapter 4 – Disease identification and management.

Plant diseases are one of the major reasons for crop losses around the world, resulting in billions of dollars in losses. This makes it vital for growers to do everything possible to control economically-important plant diseases. A plant disease is typically defined as an abnormal growth and/or dysfunction of a plant as a result of a disturbance in its normal life processes. Pathogens are living organisms like fungi, bacteria and viruses. Plant diseases can be identified based on the symptoms of the disease or the response of the host plant to the pathogen. Symptoms can include lesions, necrosis or dead plant tissue, blocked nutrient and water transport vessels, mutated reproductive structures and chlorosis or yellowing of the plant. When diagnosing a disease, we can also look for the presence of the pathogen in the form of fungal vegetative structures, called mycelium and hyphae or spores and bacterial ooze.

Seedling diseases.

Seedling infection can cause damping off both pre- and post-emergence in pulse crops. This can be the result of a single pathogen or multiple pathogens acting in complex. It can be challenging to distinguish between the symptoms caused by each type of pathogen due to additional organisms opportunistically infecting damaged tissue. Fortunately, in many cases seed treatments for lentils and peas are effective against several early season pathogens.

Field history and weather conditions can assist with identification of specific pathogens, however for exact identification a laboratory analysis is required. In field assessment of symptomology can be assisted through the use of disease handbooks such as Diseases of Field Crops in Canada by Bailey et al. (2003)[17], Field Scouting Guide by Manitoba Agriculture and Food (2002)[18], Crop Diagnostic Handbook by Government of Saskatchewan (2016)[19], the Saskatchewan Pulse Growers website[20], Manitoba Pulse & Soybean Growers website[21], the Alberta Pulse Growers website[22], and consultation with experts.

i. Aphanomyces root rot.

Aphanomyces root rot, caused by *Aphanomyces euteiches*, is a disease that can be quite detrimental in peas and lentils and has recently been identified in areas across Western Canada.

[17] Bailey, K.L., Gossen, B.D., Gugel, R.K., and R.A.A. Morrall. 2003. Diseases of Field Crops in Canada. The Canadian Phytopathological Society.

[18] Manitoba Agriculture and Food. 2002. Field Scouting Guide.

[19] Government of Saskatchewan. 2016. Crop Diagnostic Handbook. http://saskatchewan.ca/agriculture

[20] http://saskpulse.com/growing/peas/ and http://saskpulse.com/growing/lentils/

[21] http://www.manitobapulse.ca/production/pulse-school/

[22] http://pulse.ab.ca/producers/varieties-management/

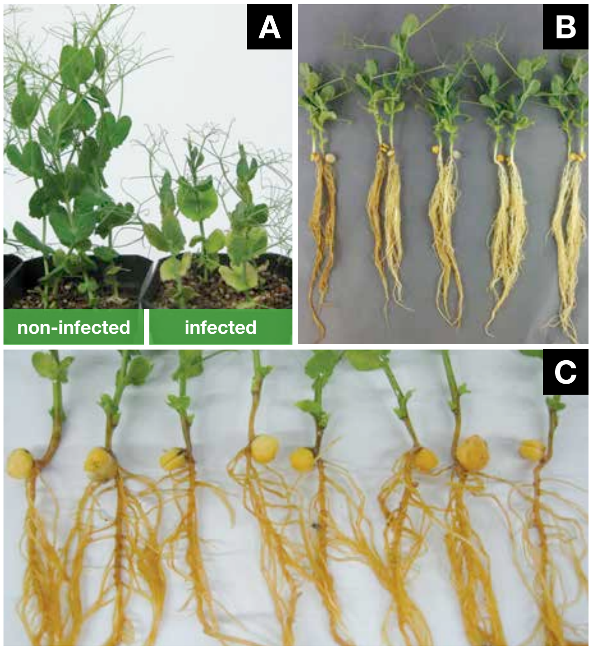


Figure 4.1. A. Stunting and yellowing of the leaves. **B.** Caramel-coloured roots. **C.** Girdling of the stem. Source: **B.** University of Saskatchewan Cheryl Cho, Dr. Sabine Banniza lab.

Symptoms.

Infection can result in pre-emergence or post-emergence damping-off, low nodulation levels and decreased root masses. Plants can become infected at any stage, but the seedling stage is most common. A characteristic symptom of aphanomyces includes tan, caramel coloured roots, which darken as secondary, opportunistic fungi infect (Figure 4.1 B). Soft, water-soaked lesions are also typically found on the lower stems and can cause stem girdling (Figure 4.1 C).[17] Yellowing or chlorosis of the leaves from the bottom up can occur and stunting and seedling death may result if infection is severe (Figure 4.1 A).[23] Late-season infection may not result in aboveground symptoms however, but significant root damage is still possible.[23]

Disease cycle.

Aphanomyces is part of the oomycete family of water molds and it is a soil-borne pathogen. The pathogen thrives in wet, waterlogged soils where it produces both motile zoospores and thick-walled oopsores. The zoospores 'swim' through the soil towards susceptible plants to infect, but are short lived in dry conditions. Oopsores are dormant structures that can survive in the soil for 10 to 20 years acting as a continuous source of inoculum. Fields with poor drainage, high compaction, heavy soil and irrigation are all prone to severe infection.

Best management practices.

Due to the longevity of the spores, crop rotation is not as effective as it is with other diseases, especially since multiple legume crops are hosts for this disease. However, long crop rotations of 6 or more years can reduce the buildup of inoculum. Proper drainage and reduced tillage are also advised. Movement of infected soil between fields increases the spread of this resilient pathogen, so sound sanitation of all equipment is recommended. There are currently no resistant cultivars available for peas and lentils, but other legume crops do have different levels of susceptibility. Field peas and lentils are the most susceptible whereas other pulse crops like faba beans, chickpeas and soybeans are more resistant. Despite the availability of a seed treatment for suppression of aphanomyces (ethaboxam), there is still no effective chemical solution to completely control this disease.

TIP

Using a seed treatment, even though it is not registered to control aphanomyces, has the additional benefits of managing other seed- and soil-borne diseases. This can lead to a healthier plant, which can more easily defend itself against aphanomyces.

[23] Government of Saskatchewan. 2016. Crop Diagnostic Handbook. http://saskatchewan.ca/agriculture

ii. Fusarium root rot.

Fusarium root rot is caused by multiple species of fusarium, including *Fusarium solani* f. sp. *pisi* in field peas, and *F. avenaceum* in lentils.

Symptoms.

The main points of infection are where the shoot and upper roots meet and where the cotyledons are attached.[24] Streaky lesions can be found on the roots, which can coalesce and cause brownish-red to black discolouration (Figure 4.2).[24] The vascular tissue of the roots may also appear reddish and plants often lack secondary roots.[25] Aboveground, plants can become wilted, stunted and yellow and girdling of the lower stem is often observed.[26]

Figure 4.2. Red discolouration from fusarium root rot.
Source: Alberta Agriculture and Forestry, Robyne Bowness.

Disease cycle.

The thick-walled spores of *Fusarium* spp. can survive in the soil for long periods of time, acting as a continuous source of inoculum. Frequent cropping of pulses can further increase these inoculum levels. Similar to most seedling diseases, this pathogen favours wet conditions, heavy soils, compaction and any other condition that can slow plant growth and vigour, such as cool temperatures and low fertility.[27]

Best management practices.

Lengthy crop rotations can help reduce inoculum levels, but it won't eliminate the disease, especially since some fusarium spores are long-lived and infect a wide host range. Planting healthy seed and using an appropriate seed treatment (fluxapyroxad, pyraclostrobin) to combat seed- and soil-borne fusarium are the best methods to protect pulses from fusarium root rot.

iii. *Pythium* spp.

Pythium is a soil-borne pathogen that is found worldwide. This pathogen infects a broad host range and has a long survivability in the soil.

Symptoms.

There are very few characteristic symptoms of pythium infection since most root rots are caused by a complex of several fungal pathogens. However, infested roots tend to have poor development and often appear brown and necrotic. Similar to other root rot diseases, the outer cortex easily peels off the inner root tissue (Figure 4.3).[25]

Figure 4.3. *Pythium* spp. in field peas.
Source: Virginia Tech Learning Resources Center,
Virginia Polytechnic Institute and State University, Bugwood.org

[24] Bailey, K.L., Gossen, B.D., Gugel, R.K., and R.A.A. Morrall. 2003. Diseases of Field Crops in Canada. The Canadian Phytopathological Society.

[25] Burrows, M. 2012. Diseases of Cool Season Legumes (Pulse Crops: Dry Pea, Lentil, and Chickpea). Montana State University Extension.

[26] Government of Saskatchewan. 2016. Crop Diagnostic Handbook. http://saskatchewan.ca/agriculture

[27] Alberta Pulse Growers, Government of Saskatchewan, Manitoba Pulse Growers Association Inc., Saskatchewan Pulse Growers, and University of Saskatchewan. 2014. Root Rot in Pea and Lentil in Western Canada.

Disease cycle.

Like aphanomyces, pythium is a water mold which makes it well adapted for movement and infection in wet soils. Pythium can be found in almost all soils, where it survives as hyphae, sporangia and long-term as oospores.

Best management practices.

Seed treatments containing metalaxyl or mefenoxam are typically effective against *Pythium* spp. (Figure 4.4).

Figure 4.4. Pythium infected field peas treated with a fungicide seed treatment (right) compared to untreated (left).
Source: BASF

iv. Rhizoctonia root rot.

Rhizoctonia is a soil-borne pathogen that is becoming more common in Western Canada.

Symptoms.

One of the characteristic symptoms of rhizoctonia infection is a reduced plant stand. Some other symptoms include poor root growth and black, soft root lesions.[25] Stem rot will also spread to emerged seedlings causing watery lesions, which are red to brown in colour. Sunken, reddish-brown lesions which form at the base of the plant can cause girdling and stunting of mature plants.[24]

Disease cycle.

Rhizoctonia solani typically survives in the soil as mycelium and is favoured by warm, wet conditions.[24] Disease severity can also increase when weeds are sprayed with a herbicide close to seeding time. The decaying weeds often harbour a large population of rhizoctonia spores, which are able to reproduce quickly on the dying plant tissue due to their saprophytic nature.[25] This is referred to as a 'green bridge'.

Best management practices.

Breaking the green bridge by delaying seeding until after treated weeds have decayed will reduce the disease pressure and the likelihood of rhizoctonia infection.[25] There are also several fungicide seed treatments available to prevent this disease from establishing on peas and lentils such as metalaxyl, pyraclostrobin and fluxapyroxad (Figure 4.5).

Figure 4.5. Rhizoctonia infected lentils treated with a fungicide seed treatment (right) compared to untreated (left).
Source: BASF

Vascular wilts.

i. Fusarium wilt.

Fusarium wilt is caused by *Fusarium oxysporum* f.sp. *lentis* in lentils and *Fusarium oxysporum* f.sp. *pisi* in field peas.

Symptoms.

F. oxysporum can infect pulses at any stage of development. At the seedling stage, plants droop, the leaves dry out and the entire seedling eventually wilts. Symptoms in more mature plants include stunting, downward curling and yellowing of leaves. The vascular tissue on the lower stem and root tissue often turns orange-brown to reddish-black and poor root development is also common. Mature infections can cause black cankers at the points where pods are attached. Plant death is usually seen in circular patterns in the field.

Disease cycle.

The spores of *F. oxysporum* can be transported via wind, water, seed or on plant stubble to infect healthy plants.[28] Optimal infection conditions are warm springs and hot summers, with soil temperatures around 25°C. At this temperature, wilt increases significantly and plant death occurs rapidly. The pathogen can also survive for long periods of time in the soil as chlamydospores.

Best management practices.

It is difficult to breed resistance for fusarium wilt because each species contain different races. Currently there are some field pea cultivars that are resistant to race 1 and 2 of *F. oxysporum* f.sp. *pisi*, as well as some lentil varieties that are resistant to *F. oxysporum* f.sp. *lentis*, however options are still limited. Breeding for resistance is important for disease management as there are currently no fungicides available to control this disease. Other management practices include proper sanitization of equipment, early planting and seed treatments.[28] These practices can help growers decrease inoculum loads, avoid ideal conditions for disease development and increase plant vigour and establishment which helps to fend off infection.

Foliar diseases affecting peas and lentils.

i. Anthracnose blight.

Anthracnose blight is caused by a fungal pathogen called *Colletotrichum truncatum* in lentils and *C. pisi* in field peas. It is an economically important and destructive disease in Western Canada, especially under warm, moist conditions where short crop rotations are practiced.

Symptoms.

White to grey lesions are first observed on the lower leaves at the 8th to 12th node stage or around flowering. The lesions then begin to spread upward where they become tan with dark edges (Figure 4.6). The lesions eventually spread to the stems and pods, leaf and leaflet drop occurs and defoliation is possible.[28] Stem lesions can also become sunken which can lead to girdling of the stem, wilting, lodging and plant death. Even low levels of infection can cause significant yield loss and can increase the inoculum levels in the field. Affected fields often have yellow patches after canopy closure, which increase in size as the disease spreads, causing the centre plants to die. Dead plant stems appear black and remain black after harvest due to microsclerotia bodies.

Disease cycle.

Microsclerotia are tiny black resting bodies that can survive on infested debris for three or more years. Microsclerotia are released during harvest and are either carried downwind or land in the soil and remain dormant. The dusts produced during harvest are considered the most important source of inoculum since these winds can carry the disease from field to field for future infections. Seed-borne inoculum is of minor importance because infected crop residue plays a more important role in the spread and survival of this pathogen. During the season, the spores can also be spread by rain splash, plant-to-plant contact or heavy dew events.

Figure 4.6. Anthracnose blight in lentils.
Source: Agriculture Victoria, DEDJTR.

[28] Burrows, M. 2012. Diseases of Cool Season Legumes (Pulse Crops: Dry Pea, Lentil, and Chickpea). Montana State University Extension.

Best management practices.

Some of the key management strategies for anthracnose include seeding clean seed, planting tolerant varieties, implementing a no till system, using a minimum 3-year rotation to a non-host crop, scouting for disease beginning at the 10th to 12th node stage through flowering and applying a foliar fungicide containing pyraclostrobin, azoxystrobin or thiabendazole near canopy closure. A second application might be necessary if disease pressure is high.

ii. Ascochyta blight/leaf and pod spot.

Ascochyta blight is caused by the fungal pathogen *Ascochyta lentis* in lentils and *A. pisi* in field peas.

Symptoms.

Infection can occur at any time from seedling to maturity. Ascochyta presents itself as grey, spot-like lesions with dark edges, which can be found on almost all structures of the plant (Figure 4.7). One of the characteristic symptoms of ascochyta blight is the target-like appearance of these lesions. The centre of these lesions are often speckled with fruiting bodies called pycnidia. Lesions on peduncles (the part of the shoot where flowers are formed) can cause flower abortion and pod loss which can greatly impact yield.[29] Infected seed will have brown or purplish-brown patches that lead to discolouration of the grain. With severe infections, the lesions can also coalesce leading to lodging, stem breakage, defoliation and dieback.

Disease cycle.

Ascochyta lentis and *A. pisi* can survive on crop residue for three or more years. Pycnidia on crop residue or on lesions produce spores that can spread to other plants through rain splash or wind. Cool, wet weather and high humidity favour disease development.

Best management practices.

Most lentil cultivars tend to be resistant to ascochyta but only a handful of pea varieties are resistant. It is recommended to avoid growing lentils and peas more than once in a four-year rotation to manage the disease. Seed treatments containing pyraclostrobin, azoxystrobin, fluxapyroxad or thiabendazole can all effectively prevent seed-borne spores from infecting other plants. A foliar fungicide application at flowering can also help to decrease flower and pod abortion and the spread to healthy plants.

Figure 4.7. Ascochyta blight in lentils (left) and field peas (right). Source: Agriculture Victoria, DEDJTR and **AgSolutions** Performance Trials, AB, 2011.

iii. Septoria blight/leaf blotch.

Septoria blight is caused by *Septoria pisi* in field peas and *Septoria lentis* in lentils.

Symptoms.

Septoria is common on field peas and has been observed to some degree on lentils in Western Canada as well. It is often confused with ascochyta blight because of their similar fruiting bodies called pycnidia

[29] Government of Saskatchewan. 2016. Crop Diagnostic Handbook. http://saskatchewan.ca/agriculture

that form as black dots inside lesions. However, septoria lesions are not concentric and target-like, which is characteristic to ascochyta, nor are the lesions always circular.[30] Lesions appear light yellow initially then become slightly darker in colour with a light centre (Figure 4.8). The lesions have indefinite margins and are bordered by a chlorotic halo.[31]

Disease cycle.

The fungus survives on crop residue and seed, giving rise to spores. These spores are carried to infect healthy crops by wind or rain events, particularly under humid conditions.

Figure 4.8. Septoria blight in field peas.
Source: Mary Burrows, Montana State University, Bugwood.org

Best management practices.

A crop rotation of three years is recommended to reduce the level of inoculum in the soil. There are no fungicides currently registered for control of septoria in peas and lentils, but it is considered a minor disease because it generally only impacts older leaves on the plant without significantly affecting yield.

iv. Botrytis/grey mold (stem and pod rot).

Botrytis or grey mold is a fungal pathogen in peas and lentils caused by *Botrytis cinerea*. Crops are particularly susceptible late in the summer when stands are heavy, fields are weedy and there has been heavy rainfall.

Symptoms.

Botrytis cinerea infects both lentils and peas, but it's primarily found in lentils. Symptoms begin as water-soaked lesions on any aerial part of the plant. Lesions are not usually observed until late flowering and are typically greyish brown in colour. These lesions can become covered with grey, fuzzy mold when infections are severe (Figure 4.9). This fungal growth is comprised of hyphae, reproductive structures and spores and physically looks like metal shavings on the plant. Infected leaves will appear wilted and yellow and the flowers often drop to infect lower parts of the plant, significantly impacting yield. Stem infections can lead to early ripening of the plant and infected pods tend to not fill and turn brown and become covered in grey fuzz. Infected fields tend to be patchy and brown.

Disease cycle.

The pathogen can survive on both seed and crop residue which can potentially lead to seedling disease. Since the pathogen has over 100 crop and weed hosts, mature plant infection is generally caused via plant-to-plant contact and wind-borne spores.[30,31] Cooler summer temperatures and high humidity favour sporulation, infection and the spread of grey mold. Heavy rain in dense crop and weed stands is therefore conducive to the spread and development of disease. *Botrytis cinerea* can be viable on seed, on stubble or remain as hardy sclerotia and chlamydospores in the soil.[31]

Best management practices.

Seed free of disease and seed treatments containing thiabendazole and fluxapyroxad can help prevent seedling infection. Increased row spacing and decreased seeding rate can allow more air movement through the crop, reducing opportunities for the disease to spread.[31] Plant tolerant varieties with characteristics like an upright or open canopy, limited

30 Bailey, K.L., Gossen, B.D., Gugel, R.K., and R.A.A. Morrall. 2003. Diseases of Field Crops in Canada. The Canadian Phytopathological Society.

31 Burrows, M. 2012. Diseases of Cool Season Legumes (Pulse Crops: Dry Pea, Lentil, and Chickpea). Montana State University Extension.

branching, shorter stature and resistance to lodging. Other cultural control methods include intercropping with plants that are non-hosts, limiting irrigation, plowing where possible and rotating crops to reduce inoculum. Applying boscalid for control and fluxapyroxad for suppression at second application timing (see Fungicide timing section, page 47) are good options for controlling botrytis grey mold.

Figure 4.9. Botrytis or grey mold in lentils.
Source: Agriculture Victoria, DEDJTR.

v. Sclerotinia stem and pod rot/white mold.

Sclerotinia stem rot or white mold in peas and lentils is caused by the fungus *Sclerotinia sclerotiorum*.

Symptoms.

This is a significant disease in both lentils and peas, resulting in up to 70% yield losses in some cases. Infections usually start as watery, pale-grey or white lesions on the stems, branches and leaves. These lesions eventually expand and become greyish-white with light brown margins. Infected stems are bleached in appearance and tend to shred and break (Figure 4.10). Hard, dark resting bodies of the fungus called sclerotia are often found inside the stems of infected plants. The severity of the disease depends on whether the main stems or branches are infected and at what stage the infection occurs. Severely infected crops frequently lodge and shatter at swathing.

Disease cycle.

Hard structures called sclerotia overwinter in soil and on crop residue and can remain viable for several years. These produce fruiting structures which release spores that infect susceptible plants with the help of wind and rain events. The spores tend to infect weak plant tissue first like flower petals or maturing leaves. Often the flower petals die, fall off and land on lower parts of the plant or branches, which allows the disease to develop on the stems and nodes in the canopy. This is why major infection events coincide with flowering or just after flowering.

Figure 4.10. Sclerotinia or white mold in lentils (left) and in field peas (right).
Source: USDA-Agricultural Research Service, 2016 https://www.ars.usda.gov/plains-area/docs/white-mold-research/about-sclerotinia/page-6/ and **AgSolutions** Performance Trials, AB, 2011.

Best management practices.

Crop rotation has limited effectiveness since sclerotia can survive in the soil for long periods of time. There are several cultural control methods that can be used to improve air flow throughout the crop to reduce humidity and lower disease incidence. These methods include using wider row spacing and reduced seeding rates. There are also several foliar fungicides (boscalid, prothioconazole, cyprodinil, fludioxonil) that are effective against sclerotinia in both peas and lentils when applied at 20 to 30% flowering or when 15 to 20 flowers are open on the main stem.

Foliar diseases affecting lentils.

i. Stemphylium blight.

Stemphylium blight on lentils is caused by a fungal pathogen called *Stemphylium botryosum*.

Symptoms.

Stemphylium blight affects lentils and some other legumes, but it does not affect field peas. This pathogen can infect lentils at any time during development. At the onset of disease, stems appear healthy and leaves appear chlorotic and yellow (Figure 4.11). Cream-coloured, angular lesions then develop and eventually turn dark brown or black. The lesions can spread across the entire leaflet causing the leaves to dry up and roll, eventually leading to defoliation of the plant.

Disease cycle.

Stemphylium thrives in wet conditions because moisture allows the pathogen to disperse spores to infect healthy plants. The fungus overwinters on crop residue and on seed. *S. botryosum* can also be found as a saprophyte on other dead plant material in nature.

Best management practices.

Due to the pathogen's saprophytic nature, crop rotation and tillage are unlikely to reduce inoculum levels in the soil. Fungicides targeting other foliar lentil diseases may provide some control of stemphylium blight. However, it typically occurs too late in the season for fungicides to be effective.

Foliar diseases affecting field peas.

i. Ascochyta disease complex

As mentioned in the previous sections, there are several different species of ascochyta that can infect field peas. It's common to refer to these pathogens collectively as ascochyta disease complex because they often occur together. This complex is made up of three different pathogens:

- *Ascochyta pinodes* (sexual stage: *Mycosphaerella pinodes*) – **Mycosphaerella blight**
  - See Foliar diseases affecting field peas, Section ii (page 44)
- *Ascochyta pinodella* (synonym: *Phoma medicaginis* var. *pinodella*) – **Ascochyta foot rot**
  - See Foliar diseases affecting field peas, Section ii (page 44)

Figure 4.11. Stemphylium blight in lentils.
Source: BASF.

- *Ascochyta pisi* – **Ascochyta blight and pod spot**
  - See Foliar diseases affecting peas and lentils, Section ii (page 40)

Because these pathogens typically occur as a complex, the individual symptoms can be difficult to identify. *Ascochyta pinodes* is the most common fungal species and it's the most economically important. Infection is caused by *Mycosphaerella pinodes,* which is the sexual stage of the fungus that produces airborne spores on field peas.

ii. Mycosphaerella blight and ascochyta foot rot.

Mycosphaerella blight and ascochyta foot rot are caused by the fungal pathogens *Mycosphaerella pinodes* and *Phoma medicaginis* var. *pinodella* in field peas. These two diseases are typically treated and managed together as they usually co-exist and are not easily distinguishable.

Symptoms.

Both fungi infect the stems, leaves, flowers and pods of field peas. Early symptoms include small, purplish-black lesions that coalesce, turn brownish-black and develop a target-like appearance (Figure 4.12). Infected flowers may drop and lesions on the stem can result in significant blight and foot rot. Small, purple lesions develop on infected pods which can result in shriveled seed. The symptoms of *P. medicaginis* var. *pinodella* are very similar to *M. pinodes* but they are less severe.

Disease cycle.

These diseases thrive in cool, wet environments which can lead to high disease pressure and yield losses of up to 80%.[32] The pathogens can be soil-, stubble- and seed-borne and they can survive in the soil for up to four years as resting spores. The spores of the fungi are mainly windborne but they can also spread from existing lesions via wind and rain splash. Infection can also occur when seedlings come in contact with resting spores in the soil or crop residue. Once the fungus becomes established in the crop, it spreads systemically through the shoots to infect the entire plant.

Best management practices.

Use disease-free seed, rotate crops to control inoculum levels (plant peas once every four years), seed away from previously infested fields and plow crop residue under after harvest, where possible. Selecting more tolerant pea cultivars can also be helpful, although complete resistance is not available. Using seed treatments can help prevent the introduction of the disease to previously un-infested fields. However, seed treatments have limited effectiveness in previously affected regions. An application of a foliar fungicide containing fluxapyroxad and pyraclostrobin at early flowering, however, can prevent disease development and decrease disease severity.[33]

Figure 4.12. Mycosphaerella blight in field peas.
Source: Agriculture Victoria, DEDJTR and Mary Burrows, Montana State University, Bugwood.org

[32] Saskatchewan Pulse Growers http://saskpulse.com/growing/peas/disease-management/

[33] Bailey, K.L., Gossen, B.D., Gugel, R.K., and R.A.A. Morrall. 2003. Diseases of Field Crops in Canada. The Canadian Phytopathological Society.

iii. Bacterial blight.

Bacterial blight is caused by a pathogen called *Pseudomonas syringae* pv. *pisi*.

Symptoms.

Bacterial blight affects fields peas but it does not affect lentils. It is commonly observed after hail or wind storms where particles containing the bacteria are blown into or onto plants. Symptoms appear as mainly water-soaked, translucent lesions on the leaves, stems, petioles and pods (Figure 4.13). The lesions are angular and limited by leaf veins, forming a characteristic fan shape. As the lesions dry, they become brown and papery and often tear. The lesions that form on pods are sunken and olive-brown.

Figure 4.13. Bacterial blight in field peas.
Source: Mary Burrows, Montana State University, Bugwood.org

Disease cycle.

Seed is the main source of inoculum, but the pathogen can also survive in the soil and on crop stubble. Bacteria also exist on leaf surfaces of other plants, which spread to healthy plants via wind and rain splash. Wounds from hail and wind damage provide a prime entry point for the bacteria.

Best management practices.

Methods to limit bacterial blight include ensuring seed is disease free before planting, rotating crops, burying residue and avoiding early seeding. Harvesting infested pea fields last and ensuring good sanitation of both equipment and personnel clothing that have come in contact with affected fields are also recommended to limit spread of the disease. There are no bactericides available to manage this blight.

iv. Downy mildew.

Downy mildew is caused by the fungal pathogen *Peronospora viciae* f. sp. *pisi*.

Symptoms.

Downy mildew is a common fungal pathogen that affects field peas. The characteristic symptom of the disease is white to grey fluffy patches on the lower surface of leaves. The fuzzy patches can also spread to the stems and pods. Chlorosis or yellowing is observed on the upper surface of leaves (Figure 4.14). The fungus can move systematically throughout the plant and cause stunting, distorted growth and plant death.[34]

Disease cycle.

The pathogen survives in soil and on seed and can also be present on field stubble. Infected seed or soil often act as the primary source of inoculum for systemic infections. The disease develops quickly when conditions are cold and wet for several days.

Figure 4.14. Downy mildew in field peas.
Source: Agriculture Victoria, DEDJTR.

[34] Bailey, K.L., Gossen, B.D., Gugel, R.K., and R.A.A. Morrall. 2003. Diseases of Field Crops in Canada. The Canadian Phytopathological Society.

This often happens when seedlings are in the early vegetative stage. High levels of moisture are favourable for spore dispersal and secondary infection.[34]

Best management practices.

A crop rotation of two to three years will help to reduce the level of inoculum in the soil.[34] There are foliar fungicides registered for use on field peas to control downy mildew like boscalid, which should be applied at the second fungicide application (See Fungicide timing section, page 47).

v. Powdery mildew.

Powdery mildew is caused by the fungal pathogen *Erysiphe pisi*. Late-maturing field pea varieties are more prone to infection and the disease can cause up to 60% yield loss in severe epidemics. However, most commonly grown pea varieties are resistant to powdery mildew.

Figure 4.15. Powdery mildew in field peas.
Source: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org

Symptoms.

Symptoms begin as powdery, white spots on the upper surface of the oldest leaves and can easily be rubbed off. Powdery mildew rapidly spreads to cover the leaves, stems and pods with a fine, powdery, bluish-white growth. As the disease progresses and plants mature, fruiting structures form in the infections, appearing as brown or black dots (Figure 4.15).

Disease cycle.

The pathogen survives on infested crop debris in fields as fruiting bodies, but it is unverified that the spores released from these structures are able to overwinter and cause infection the next season in Western Canada. Spores produced from foliar infections can travel long distances by air currents and wind. This leads to increased disease pressure and secondary infections throughout the season. Spore germination is favoured by warm daytime temperatures followed by cool nights with high levels of dew. Rain does not favour this disease as it causes spores to burst. Powdery mildew development occurs earlier in dry years compared to normal or high precipitation years. The disease leads to uneven crop maturity which complicates harvest timing. Desiccants are not helpful in heavily diseased crops because they cannot penetrate through the powdery mass.[35]

Best management practices.

It is recommended to use early-maturing cultivars and to seed earlier. Additional methods to control powdery mildew include crop rotation, burying/plowing crop residue and seeding away from previously affected fields. However, since infection in Western Canada mostly occurs from spores travelling via air currents, these strategies have limited effectiveness. Applying a foliar fungicide containing sulphur, boscalid, or pyraclostrobin 10 to 14 days after the first application is the most viable option for powdery mildew prevention.

[35] Burrows, M. 2012. Diseases of Cool Season Legumes (Pulse Crops: Dry Pea, Lentil, and Chickpea). Montana State University Extension.

FUNGICIDE APPLICATION EVALUATION FACTORS.

Inspect at least 10 locations in your pulse crop at 10% flowering.

Disease Potential

- Frequency of host crops in rotation
- Presence of host crop residue
- Disease incidence in the previous growing season
- Single or multiple infection periods
- Proximity to other host crops or weeds
- Dense, early row closure
- Part of plant affected by the disease (i.e. stem diseases causing lodging, foliar diseases reducing photosynthetic potential, flower diseases affecting yield and quality)

Weather Potential

- Frequency of rain during the last 10 to 14 days
- Potential for rainfall in next 10 to 14 days
- Heavy dews
- High humidity
- Moisture inside the canopy
- Wind
- Moderate temperatures

Yield Potential

- Lentils with potential of 20 bu/ac or more
- Field peas with potential of 30 bu/ac or more
- Varieties with commodity prices
- Susceptible or tolerant varieties

Figure 4.16. Evaluation factors for applying a fungicide.

Disease management check list.

Making informed disease management decisions is important to prevent yield loss. It is essential to consider a realistic yield potential and the weather conditions or disease forecasting, in addition to several other factors. Figure 4.16 gives a general sense of whether a fungicide application would be economically beneficial. However, consulting an agronomic professional is also recommended.

Fungicide timing.

First application.

The most important fungicide application is a preventative one. The optimal application timing for peas and lentils can vary depending on the disease. Scouting is an important tool to help growers make spray decisions and it should be done at or just before first flower. Scouting allows for proper evaluation of the field conditions and crop quality. This is especially important because pathogens should always be managed preventatively as opposed to waiting for symptoms to develop on the crop. The first application should occur at early to mid-flower or before row closure to ensure adequate coverage. Applying at this time allows the fungicide to disperse to the stems and lower leaves to effectively control ascochyta blight, anthracnose blight, mycosphaerella blight and ascochyta foot rot. If the early flower timing is missed and the crop canopy closes, it is unlikely that the product will be able to protect the lower portion of the canopy.

Second application.

Under high disease pressure, a second application can provide additional return on investment (ROI). Growers will want to monitor for diseases that occur later in the season, like white and grey mold. Scouting 10 to 14 days after the first application can help growers determine whether a second application will be beneficial. Factors a grower will take into account when considering a second application are:

- History of disease in field
- Tight rotations of susceptible crops
- The use of susceptible cultivars
- Continuous wet conditions 7 to 10 days after the first application
- Hail damage – susceptible area for disease to enter
- High commodity prices

A second fungicide application at mid to late flowering (with different or additional modes of action) will help protect against sclerotinia stem and pod rot/ white mold, botrytis/grey mold and powdery mildew, which can all develop later in the season.

Water volumes and nozzles.

While spindly during the initial stages of growth, pea and lentil crops eventually form a dense canopy which is fairly impenetrable. This presents challenges when it comes to foliar fungicide applications and proper coverage. There are some tips growers can use to make their fungicide applications more effective. First and foremost, growers should use more water for pulse crops compared to other crops like cereals or canola. Using a minimum of 10 gallons per acre (gpa) of water is recommended for ground application for foliar diseases that target the top leaves and flowers. For aerial application, a minimum of 5 gpa of water is recommended.

For diseases that impact the lower parts of the plant and are not easily visible from the top of the canopy, higher water volumes are recommended (15 gpa) to increase the likelihood of the fungicide reaching the lower canopy.[36] High water volumes have the greatest impact on fungicide efficacy over both droplet size and application pressure.[37]

In ideal spraying conditions, nozzles with fine droplets provide the best coverage, especially in dense canopies. Fine droplets can be generated with either high pressure or fine nozzle tips.[36] However, finer droplets easily drift in the wind and can evaporate quickly. Thus, in less than ideal conditions, medium to coarse droplets at high water volumes can still provide good coverage, especially since leaves can catch a range of droplet sizes.[37] Similar to cereal crops, twin nozzles are not necessary for fungicide applications in pulse crops because they are more vertically orientated. Slower speeds of around 10 miles per hour (mph) are also advantageous for application, if possible.[36]

Fungicide resistance management and stewardship.

Fungicide resistance occurs when a fungal population shows decreased or limited sensitivity to a fungicide. In other words, the fungicide will have little to no effect on a resistant population at the same concentration that would inhibit a sensitive population. Resistant characteristics occur naturally at very low frequencies in fungi. However, mutations in fungal populations can also be selected for through repeated use of the same product or products with the same mode of action. It is the repeated use of the same fungicide or the

[36] Wolf, T. Fungicide Application in Cereal, Pulse, and Oilseed Crops. http://sprayers101.com/fungicide-application-in-cereal-pulse-and-oilseed-crops/

[37] Wolf, T. Fungicide Application Basics. http://sprayers101.com/fungicide-application-basics/

same mode of action that increases the frequency of these resistant characteristics and leads to the development of resistance. It is important to remember that fungicides don't change the fungus, they change the population structure. This change can occur via two types of resistance. The first is when low levels of fungicide resistance occurs without any noticeable loss of fungicide efficacy. This is sometimes referred to as shifting resistance where the population is shifting toward a resistant one, but not all individuals are resistant yet. The second type of resistance is called practical resistance. This occurs over time as the resistant populations become dominant. A rapid loss of efficacy is observed due to significant changes in the population dynamics, ultimately leading to economic damage.

Resistance is a reality for all site-specific fungicides, some of which are at greater risk than others. Site specific fungicides comprise the vast majority of the products on the market and include but are not limited to Group 3 (triazoles), Group 7 (SDHI) and Group 11 (strobilurin). For successful resistance management, it is necessary to reduce fungicidal pressure on the disease. There are several strategies that can be used to mitigate the risk of resistance:

1. Chemical management strategies.

- Develop spray schedules with different modes of action – alternations and mixtures
- Minimize the use of at-risk fungicides by combining or alternating with other fungicides
- Apply fungicides only when necessary
- Ensure applications are timed properly
- Apply preventatively so disease pressure remains low
- Always apply labelled commercial rate of fungicide
- Maximize spray coverage by adjusting methods
- Use seed treatments to manage seed- and soil-borne diseases

2. Non-chemical management strategies.

- Plant disease-resistant varieties
- Use clean seed
- Rotate to non-host crops
- Avoid over-fertilization – extremely lush canopies can be conducive for disease development

3. Resistance monitoring.

As part of product stewardship and risk management, monitoring for resistance is necessary to:

- **Determine the sensitivity** of pathogen populations to fungicides
- **Monitor fungicide performance** after introduction
- **Evaluate the effectiveness** of resistance strategies and provide information for the development of new ones
- **Test isolate sensitivity** in cases of reduced performance
  – Collect samples after application where reduced performance occurred and take to an accredited lab or Ag Canada facility where resistance isolate monitoring can be completed. Consult an agronomist on the best methods to collect and store samples.
- **Confirm** the development of practical resistance

Growers, agronomists and anyone else involved should:

- Report suspected cases of resistance
- Send samples to the appropriate testing facility

More information regarding fungicide resistance is available online at http://www.frac.info/.

Chapter 5 – Insect management.

There are several insect pests that affect lentils and peas; grasshoppers and cutworms are of particular economic importance. Regardless of the type, any target insect can impact crop yield and crop quality if a certain threshold is reached and best management practices are not used. The following descriptions will outline the pulse crop pests in Western Canada, how to identify them, thresholds for spraying and some general information on insecticide use.

Figure 5.1. Army cutworm.
Source: Joseph Berger, Bugwood.org

Cutworm (*Agrotis* and *Euxoa* spp.).

Although there are several species of cutworms, only a few specific species directly affect pulse crops. Some of these include army cutworm (Figure 5.1), dingy cutworm and redbacked cutworm (Figure 5.3), all of which attack the foliage and various other cutworms that feed below ground. Pale western cutworm moths lay eggs in loose soil and are common in the brown soil zones (Figure 5.2). Cutworms generally pose a low risk for pulse crops, but they can occasionally cause problems. Larvae from overwintered eggs can feed on new shoot growth and cut off growth at or below the soil surface. Under favourable conditions, such as cool, moist weather, plants tend to recover from this injury by re-growing from a scale node. Affected plants are generally delayed compared to the other plants and this can complicate pesticide application and harvest timing.

Figure 5.2. Pale western cutworm.
Source: Phil Sloderbeck, Kansas State University, Bugwood.org

Larvae are approximately 1.5” in size and adult cutworms are moths.

Figure 5.3. Redbacked cutworm.
Source: John Gavloski, Manitoba Agriculture, Food and Rural Development.

Grasshopper (*Melanoplus* spp.).

Of the approximately eighty species of grasshoppers in the prairies, only ten target crops and only three target pulse crops. These three include the two-striped grasshopper (*Melanoplus bivittatus*) (Figure 5.4), Packard’s grasshopper (*Melanoplus packardii*), and the lesser migratory grasshopper (*Melanoplus sanguinipes*).[38] Lentil and pea foliage are not typically hosts for grasshoppers, but they can do damage

[38] Bailey, K.L., Gossen, B.D., Gugel, R.K., and R.A.A. Morrall. 2003. Diseases of Field Crops in Canada. The Canadian Phytopathological Society.

when they feed on the plant structures from budding to early pod formation. Damage to the pods affect both yield and maturity because when pods shatter, the plant attempts to compensate for the seed loss. Quality can also be impacted, as chewed pods make seeds more susceptible to disease and staining. Grasshoppers that enter the combine also detract from the yield because the heads tend to break off and get mixed in with the seed. The heads are similar in size to lentil and pea seed so they often don't get removed.

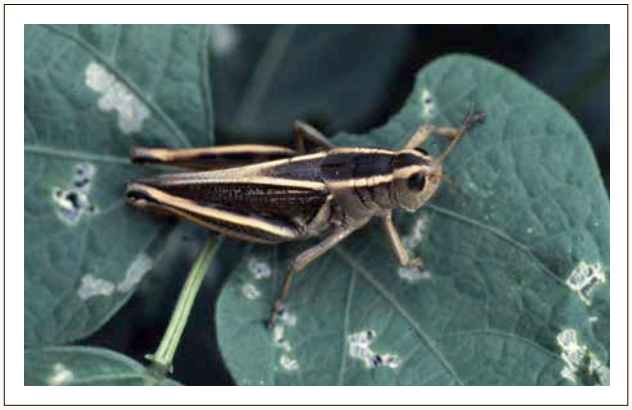


Figure 5.4. Two-striped grasshopper.
Source: Whitney Cranshaw, Colorado State University, Bugwood.org

Severe grasshopper infestations are more prevalent in dry, sandy environments or when drought occurs for a repeated number of years. Government agricultural sectors in Manitoba, Saskatchewan and Alberta conduct surveys and forecast predicted grasshopper severity every growing season. This is a useful tool to help evaluate pest pressure and management strategies.

Lygus bug (*Lygus* spp.).

Species of *Lygus*, often called the lygus bug, the tarnished plant bug or the pale legume bug, are pests to both peas and lentils. As of 2016, they have not been a significant problem in Western Canada, but they do impact lentil crops in the US. Lygus bugs typically move from alfalfa or hay fields that have been cut and find refuge in pea and lentil fields, where they feed and reproduce. Both immature and adult bugs feed on seeds and pods, injecting a toxin that causes shriveling and chalk spot on the seed. Overall this causes a decrease in seed quality.

Adult lygus bugs are small (1/4" or 6 mm) and pale green to reddish-brown in colour. They have a characteristic yellow V-shape on their back (Figure 5.5). Mature nymphs will have similar colouring to adults but the distinctive 'V' is not visible, instead there are five black dots on the thorax and abdomen (Figure 5.6).[39] The beginning of wing growth is noticeable at the nymph stage.

Figure 5.5. Adult lygus bug.
Source: Whitney Cranshaw, Colorado State University, Bugwood.org

Figure 5.6. Lygus bug nymph.
Source: Ronald Smith, Auburn University, Bugwood.org

Pea aphid (*Acyrthosiphon pisum* (Harris)).

Aphids are cyclical, which means they produce many generations within one growing season. They typically overwinter in alfalfa, vetch and clover fields. Field pea plants are quite susceptible to aphid damage from flowering to pod set. During a drought, aphid feeding can result in fewer pods and small seeds. Heavy rains and predatory insects, such as

[39] Bailey, K.L., Gossen, B.D., Gugel, R.K., and R.A.A. Morrall. 2003. Diseases of Field Crops in Canada. The Canadian Phytopathological Society.

parasitic wasps and ladybugs (ladybird beetles), can help control pea aphid populations.

Pea aphids are green in colour, and are only about 1/8" in length (Figure 5.7, 5.8).

Figure 5.7. Pea aphid.
Source: Phil Sloderbeck, Kansas State University, Bugwood.org

Figure 5.8. Pea aphid and nymphs.
Source: Joseph Berger, Bugwood.org

Pea leaf weevil (*Sitona lineatus* Linnaeus).

Faba beans and field peas are the only hosts for pea leaf weevil larvae, however the adult insects can also live on other legumes. The adults overwinter in soil near perennial legumes and begin to move by flying in warm weather or walking in the spring. Female adults lay up to 300 eggs near or on growing plants. Once the eggs develop into larvae, they begin to feed on the rhizobial nodules of the pea roots. This hinders plant growth since the plants cannot efficiently fix nitrogen (Figure 5.9). Adults continue feeding on pulse crops before eventually overwintering. The damage appears as notches on leaf edges but this type of damage does not usually cause economic loss.[40] There are multiple beetle species which act as natural predators by feeding on the eggs. Trap crops and healthy plants can help manage weevil populations. Seed treatments are also effective against larvae and foliar sprays can help to eliminate adults.

Pea leaf weevils are brown in colour and approximately 5 mm long, with a blunt nose. They also have three light stripes present on the thorax, sometimes continuing onto the abdomen (Figure 5.11). Larvae are milky coloured, 3.5 to 5.5 mm in length, c-shaped and legless, with a dark brown head (Figure 5.10).

Figure 5.9. Damage to nodules from pea leaf weevil larvae.
Circle on left shows larva feeding.
Source: Andrew Reid, BASF.

Figure 5.10. Pea leaf weevil larvae.

Figure 5.11. Adult pea leaf weevil.
Source: Ken Walker, Pest and Diseases Image Library, Bugwood.org

[40] Agriculture and Agri-Food Canada. 2015. Field Crop and Forage Pests and their Natural Enemies in Western Canada.

Wireworm (*Agriotes* spp. and *Ctenicera destructor* (Brown)).

Wireworms are 'click' beetle larvae. Although they target cereals, canola and potatoes to a greater extent, they have also been known to damage lentils and peas. They function by shredding the plant tissue found below ground, which can go unnoticed until wilting and plant death is observed. The only way to protect against wireworm damage is with insecticide seed treatments.

Wireworms are hard, slender worms about 1 to 2" in length with a yellow to coppery colour and have a notched appearance (Figure 5.12).[41] The adult versions, different click beetles, are brown to black in appearance or lined as shown (Figure 5.13).

Figure 5.12. Wireworms (Click beetle larvae).

Figure 5.13. Adult lined click beetle.

Insect scouting and thresholds.[42]

Spraying threshold levels are generally monitored by using a sweep net. A determined number of sweeps are conducted in random spots within a field and the number of the insects are counted. Sweeps are to be between 25 and 180 degrees at a specified number of locations, with a 15" diameter net.

Cutworm threshold.

The economic threshold for cutworms in lentils is 2 to 3/m^2 in the first 7.5 cm/3" of soil.

Grasshopper threshold.

At flowering and pod set in lentils, the threshold for grasshoppers is 2/m^2. For field peas, the in-field threshold is 8 to 14/m^2 or >20/m^2 in the field margins (edges). If the grasshoppers are targeting pods and flowers, the threshold is closer to the lentil threshold of 2/m^2. The threshold for nymphs in field peas is 30 to 45/m^2.

Lygus bug threshold.

The recommended threshold for lygus bugs is when 7 to 10 bugs are present after 25 sweeps at 180 degrees, using a net at five random points in a field during flowering and seed set.

Pea aphid threshold.

The common threshold for pea aphids is when 30 to 40 aphids are present per 180-degree sweep or when 10 aphids per plant are present between formation of the 10th node and the appearance of the first flower. If this level is reached, apply insecticide when 50% of pea plants have young pods.

[41] Manitoba Agriculture and Food. 2002. Field Scouting Guide.

[42] Saskatchewan Pulse Growers. http://saskpulse.com/growing/lentils/insect-management/

Pea leaf weevil threshold.

The ideal timing to scout for pea leaf weevil is when field peas are between the 2nd and 3rd node stage. The primary concern is damage on the clam leaf or the most recently emerged leaf. The economic threshold occurs when one or more feeding marks are present per three clam leaf pairs (30% of plant stand has damage on the clam leaf).

Wireworm threshold.

There is currently no threshold for the presence of wireworms since no in-crop insecticide is currently available. If wireworms are an issue in the soil, especially after canola or a cereal crop, the use of an insecticide seed treatment would be the most effective strategy to protect pulse crops.

Choosing an insecticide.

Below are the insecticides registered for use on common pea and lentil pests (Table 5.1, 5.2). It's important to consult the label and/or your agronomist before deciding on the appropriate insecticide for your operation.

Table 5.1. Insecticides for use in field peas (adapted from Saskatchewan 2016 Guide to Crop Protection p. 515).

Insect	Insecticide	Insecticide Group	Application	Oral LD50 (Mammalian Toxicity mg/kg body weight)
Belowground and Surface Feeders				
Wireworms	Cruiser Maxx® Pulses	Neonicotinoid (4A)	Seed treatment containing Cruiser 5FS and Apron Maxx® RFC	5000
	Cruiser 5FS	Neonicotinoid (4A)	On-farm application at low rate only. Only commercial seed treater with closed system, for high rate.	> 5000
	Stress Shield® 600	Neonicotinoid (4A)	Seed treatment	> 300 – < 2000
Cutworms	Coragen®	Diamide (28)	Aerial or ground	> 5000
	Matador® / Silencer®	Pyrethroid (3A)	Aerial or ground	64 – 110
	Pounce® / Perm-UP® Ambush	Pyrethroid (3A) Pyrethroid (3A)	Ground	1030
Sap and Fluid Feeders				
Pea aphid	Movento®		Ground	> 2000
	Matador / Silencer	Pyrethroid (3A)	Aerial or ground	64 – 110
	Voliam Xpress®	Diamide (28) + Pyrethroid (3A)	Aerial or ground	98
	Lannate®	Carbamate (1A)	Ground	30 – 34
	Malathion 85E	Organophosphate (1B)	Aerial or ground	5500
	Lagon® / Cygon® 480 EC	Organophosphate (1B)	Aerial or ground	60 – 450
Defoliators				
Grasshoppers	Coragen	Diamide (28)	Aerial or ground	> 5000
	Matador / Silencer	Pyrethroid (3A)	Aerial or ground	64 – 110
Pea leaf weevil	Cruiser Maxx Pulses	Neonicotinoid (4A)	Seed treatment combining Cruiser 5FS and Apron Maxx RTC	5000
	Cruiser 5FS	Neonicotinoid (4A)	On-farm application at low rate only. Only commercial seed treater with closed system, for high rate.	> 5000
	Stress Shield 600	Neonicotinoid (4A)	Seed treatment	> 300 – < 2000
	Matador / Silencer	Pyrethroid (3A)	Aerial or ground	64 – 110

IT IS ESSENTIAL TO ALWAYS CONSULT THE INSECTICIDE LABEL BEFORE APPLYING ANY INSECTICIDE.

Table 5.2. Insecticides for use in lentils (adapted from Saskatchewan 2016 Guide to Crop Protection p. 511)

Insect	Insecticide	Insecticide Group	Application	Oral LD50 (Mammalian Toxicity mg/kg body weight)
Belowground and Surface Feeders				
Wireworms	Cruiser Maxx Pulses	Neonicotinoid (4A)	Seed treatment containing Cruiser 5FS and Apron Maxx RFC	5000
	Cruiser 5FS	Neonicotinoid (4A)	On-farm application at low rate only. Only commercial seed treater with closed system, for high rate.	> 5000
	Stress Shield 600	Neonicotinoid (4A)	Seed treatment	> 300 – < 2000
Cutworms	Coragen	Diamide (28)	Aerial or ground	> 5000
	Decis® 5EC	Pyrethroid (3A)	Aerial or ground	395
	Matador / Silencer	Pyrethroid (3A)	Aerial or ground	64 – 110
	Pounce / Perm-UP Ambush	Pyrethroid (3A) Pyrethroid (3A)	Ground	1030
	Chlorpyrifos (pale western cutworm only)	Organophosphate (1B)	Aerial or ground	205 – 418
Sap and Fluid Feeders				
Lygus bugs	Matador / Silencer	Pyrethroid (3A)	Aerial or ground	64 – 110
Pea aphid	Movento 240 SC	Tetramic acid derivative (23)	Aerial or ground	> 2000
	Matador / Silencer	Pyrethroid (3A)	Aerial or ground	64 – 110
	Voliam Xpress	Diamide (28) + Pyrethroid (3A)	Aerial or ground	98
Defoliators				
Grasshoppers	Coragen	Diamide (28)	Aerial or ground	> 5000
	Decis 5EC	Pyrethroid (3A)	Aerial or ground	395
	Matador/Silencer	Pyrethroid (3A)	Aerial or ground	64 – 110
	Malathion 500	Organophosphate (1B)	Aerial or ground	4302
	Malathion 85E	Organophosphate (1B)	Aerial or ground	5500
	Chlorpyrifos	Organophosphate (1B)	Aerial or ground	205 – 418

IT IS ESSENTIAL TO ALWAYS CONSULT THE INSECTICIDE LABEL BEFORE APPLYING ANY INSECTICIDE.

Insecticide application best practices and resistance management.

Like any pesticide, there are several best practices that can improve efficacy and stewardship when utilizing insecticide products. These include the following:

- Provide beekeepers 48 hours' notice before applying an insecticide close to where honeybees are kept
  - Best to spray at dawn or dusk (after 8 pm) when honeybees are not foraging
- Applying an insecticide to the border edges of a field for grasshoppers is often effective
  - They prefer more open canopies and will likely remain in those areas rather than moving into the field if the crop is dense
- It is often advantageous to plant a strip of 'trap' plants
  - Trap plants are planted earlier or have an earlier maturity, so they reach the ideal insect-target timing before the real crop emerges
  - 'Trap' the insects to lessen the damage
  - The trap will also prevent resistant insects from reproducing and being maintained in the population[43]
- Use various control strategies, not just synthetic insecticides
  - Use cultural practices, rotation to crops targeted by different insects, beneficial insects, weed control (host for insects) and biological insecticides when available
- Ensure spraying is timed accurately when pest is most vulnerable[44]
- Use only recommended insecticide rate, mix properly and apply carefully
- Do not tank mix with other insecticides with the same mode of action
  - Creates higher selection pressure on resistant individuals[45]
- Tank mixing products with different modes of action has superior insect control but cannot be used long term as it will also select for pests with multiple resistances
- Avoid repeated use of the same mode of action within same crop season or sequential years
- Avoid persistent chemicals
  - Best to use options that do not last in the environment[46]
- Rotate chemicals for each generation of the insect[46]
  - Assists with maintaining effectiveness
- If only one insecticide is fully effective, use less effective ones when pressure is low, so the better product can be used when pressure is high and the need for efficacy is more important
- Where soil erosion is not a concern, tillage is recommended to bury crop residues
  - Removes food source for both susceptible and resistant insects[43]
  - Prevents insect overwintering

Overall, scouting is one of the most important management strategies for insect control as it allows for the proper identification and determination of thresholds for each pest. Once these thresholds are reached, numerous cultural and chemical strategies can be utilized to manage populations and ensure a healthy pulse crop.

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[43] Manitoba Agriculture and Food. 2002. Field Scouting Guide.

[44] Insecticide Resistance Action Committee. About: Resistance: Management. http://www.irac-online.org/about/resistance/management/

[45] Bethke, J.A. 2016. UC IPM Pest Management Guidelines: Floriculture and Ornamental Nurseries: Managing Pesticide Resistance. University of California Agriculture & Natural Resources. http://ipm.ucanr.edu/PMG/r280390311.html#REFERENCE

[46] Government of Saskatchewan. 2016. Crop Diagnostic Handbook. http://saskatchewan.ca/agriculture

Chapter 6 – Harvest management.

Both pea and lentil crops have an indeterminate growth habit. This means they typically require a stressor to help the plants reach physiological maturity. While drought conditions or frost events are sometimes effective triggers for the plants to advance, these stressors are not reliable methods. Depending on the relative maturity rating of the variety, growers typically use desiccation, harvest aids or swathing to speed up the process. These methods need to be utilized at very specific times to optimize the yield and quality of the crop.

Figure 6.1.A. Optimal timing for pre-harvest herbicide application in field peas.
Source: BASF.

Figure 6.1.B. Timing is too early for pre-harvest herbicide application in field peas.
Source: BASF.

Signs of maturity – Field peas.

Pea plants ripen from the bottom up, therefore not all the pods will dry down at the same time. Desiccation and harvest aid application is recommended when:

- Approximately 75% of the pea pods have turned yellow to brown in colour on the majority of the plants in a field
- Remaining pods (25%) will likely still be green but the peas should be firm
- Bottom of the plant should have ripe, tan pods, the middle of the plant should have yellow to tan pods and the upper portion of the plant should have green pods that are turning yellow (Figure 6.1 A)[47]
- A vein pattern should also be apparent on the topmost pods[48]
- Seed moisture content should be below 30% before application of a desiccant or harvest aid herbicide application[48,49]

It is too early for a harvest aid application when 50% of the pea pods are green and the pods that are starting to dry down have peas inside that are still soft and can be split by squeezing (Figure 6.1.B).

[47] Endres, G., Forster, S., Kandel, H., Pasche, J., Wunsch, M., Knodel, J., and K. Hellevang. 2016. Field Pea Production. NDSU Extension Service.

[48] Manitoba Agriculture and Food. 2002. Field Scouting Guide.

[49] Bailey, K.L., Gossen, B.D., Gugel, R.K., and R.A.A. Morrall. 2003. Diseases of Field Crops in Canada. The Canadian Phytopathological Society.

On the contrary, applying a harvest aid too late increases the amount of pod shatter and seed loss, weather damage and earth tag or staining from disease.[49] Additionally, field pea harvest should begin as soon as possible to reduce the development of bleached seeds, which is a problem near maturity when conditions are humid, warm and there is abundant sunlight.[48]

Straight cutting or combining of windrows should proceed when seed moisture content is between 18% and 20%.[48,49]

Signs of maturity – Lentils.

Lentil plants also ripen or mature from the bottom up. The optimal timing for swathing or harvest aid application is when:

- Bottom 15% of the pods are yellow to brown with ripened lentil seeds inside that are firm when squeezed and rattle within the pod[50]
- Upper pods will likely still be green at this time and flowering may still be occurring with the most indeterminate varieties (Figure 6.2 A)[51]

Timing is too early for application if the bottom pods have not ripened and minimal colour change has occurred or when the seeds are not firm and no rattling can be heard (Figure 6.2.B). If harvest commences before the described signs of physiological maturity, yield will be reduced and quality can also be impacted. To ensure correct timing, do not scout the field from the road, but inspect plants in the field. What may appear to be a green field from a distance as too early for pre-harvest methods, may actually be ready for harvest upon closer inspection.

When lentil seed moisture reaches 18%, it is acceptable to combine either the swathed windrows or the desiccated standing crop.[52]

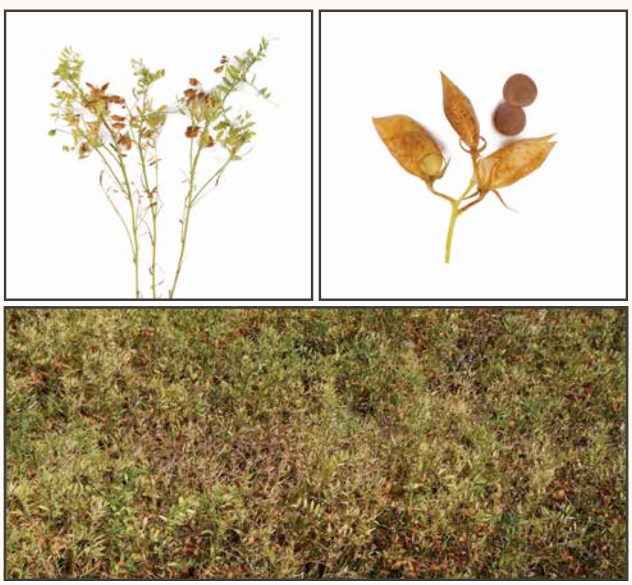

Figure 6.2.A. Optimal timing for pre-harvest herbicide application in lentils.
Source: BASF.

Figure 6.2.B. Timing is too early for pre-harvest herbicide application in lentils.
Source: BASF.

[50] Saskatchewan Pulse Growers. 2000. Pulse Production Manual 2000.

[51] Saskatchewan Pulse Growers. n/a. Lentil Production Manual.

[52] Saskatchewan Pulse Growers. 2016. Growing>Lentils>Harvest and Storage. http://saskpulse.com/growing/lentils/harvest-and-storage/

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Weeds of the Prairies – For purchase at Alberta Agriculture and Rural Development. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex39

Weed Seedling ID Booklet – For purchase at Saskatchewan Ministry of Agriculture Regional Offices.

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